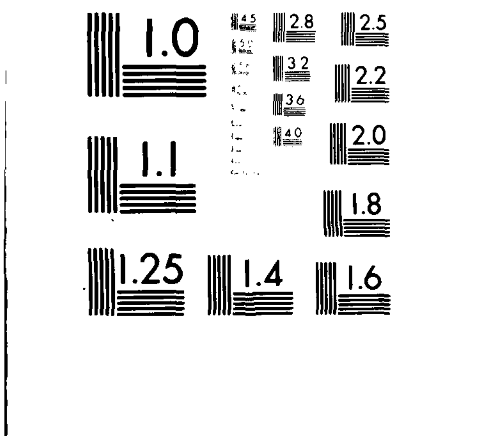
AD-A087 358 DECISION-SCIENCE APPLICATIONS INC ARLINGTON VA F/G 17/9
DEVELOPMENT AND EVALUATION OF AN EMISSIONS CONTROL DECISION AID--ETC(U)
JUL 80 D F NOBLE, G F PUGH, J E DENSMORE N00014-77-C-0322
UNCLASSIFIED DSA-246 NL

1 of 2
AD A
087358



MICROCOPY RESOLUTION TEST CHART

15 LEVEL II (12)

DSA No. 246

DEVELOPMENT AND EVALUATION OF AN EMISSIONS CONTROL DECISION AID

INTERIM REPORT

Approved for public release; distribution unlimited.

prepared under contract N00014-77-C-0322
interim report period July 1978 - July 1979

prepared for:

OFFICE OF NAVAL RESEARCH
Department of the Navy
800 North Quincy Street
Arlington, Virginia 22217

July 1980

DECISION-SCIENCE APPLICATIONS, INC.
1500 WILSON BOULEVARD, SUITE 810, ARLINGTON, VIRGINIA 22209

This work was supported by the Engineering Psychology Programs, Office of Naval Research, under contract number N00014-77-C-0322. The United States Government is authorized to reproduce and distribute reprints for governmental purposes.

DSA No. 246

DEVELOPMENT AND EVALUATION OF AN EMISSIONS CONTROL DECISION AID

INTERIM REPORT

Approved for public release; distribution unlimited.

prepared under contract N00014-77-C-0322
interim report period July 1978 - July 1979

prepared for:

OFFICE OF NAVAL RESEARCH
Department of the Navy
800 North Quincy Street
Arlington, Virginia 22217

July 1980

DECISION-SCIENCE APPLICATIONS, INC.
1500 WILSON BOULEVARD, SUITE 810, ARLINGTON, VIRGINIA 22209

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO. AD-A087358

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 Development and Evaluation of an Emissions Control Decision Aid.

5. ~~TYPE OF REPORT & PERIOD COVERED~~
9 Interim Report, Jul[redacted]78 – Jul[redacted]79

6. PERFORMING ORG. REPORT NUMBER
DSA No. 246

7. ~~AUTHOR(s)~~
10 David F. Noble George E. /[illegible]
James E. /[illegible], Jr. Max T. /Nunenkamp

8. CONTRACT OR GRANT NUMBER(s)
15 N00014-77-C-0322

9. ~~PERFORMING ORGANIZATION NAME AND ADDRESS~~
Decision-Science Applications, Inc.
1500 Wilson Boulevard, Suite #810
Arlington, Virginia 22209

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
500126

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research
Department of the Navy
800 N. Quincy St., Arlington, Virginia 22217

12. REPORT DATE
11 Jul[redacted]980

13. NUMBER OF PAGES
117 12 146

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
14 DSA-246

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

decision aid, EMCON plan, surveillance effectiveness

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side

393157

JCB

The DSA emissions control decision aid assists with the design and evaluation of emissions control plans. As part of the Office of Naval Research operational decision aiding program, the aid was formally evaluated in tests conducted by an independent ONR consultant. This report describes modifications to the aid, preparation of user's manuals for test subjects, and development of scenarios for the test program. Aid improvements occurred primarily in response to suggestions during briefings, and suggest general principals of display design. The process for scenario development described here insured a set of test scenarios appropriate for an evaluation program. The user's manuals, included in the appendices describe how to use the aid to prepare EMCON plans.

CONTRIBUTORS

The following individuals
have contributed to this report.

David F. Noble

George E. Pugh

James E. Densmore, Jr.

Max T. Nunenkamp

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

This document summarizes DSA's work for ONR's Operational Decision Aiding Program between July 1978 and July 1979. Activities during that period focused on preparations for the formal aid evaluation tests which were conducted in the summer of 1979. These activities included improving those displays likely to be most important in the tests, learning to use the aid efficiently during shakedown trials by DSA, and supporting the aid evaluations by writing documents, preparing test scenarios, and responding to other requests by the aid evaluators.

1.1 BACKGROUND ON THE EMISSIONS CONTROL DECISION AID (EWAR)

The emissions control decision aid assists with the design and evaluation of EMCON plans. It includes displays for data retrieval, for the evaluation of surveillance quality and information given away, and for the analysis of the trade-off between surveillance quality and information given away. Work on the emissions control decision aid began early in 1976. The first year's efforts concentrated on selecting a task force planning problem appropriate for a computerized decision aid, on testing mathematical concepts required for this planning problem, and on outlining the basic aid design. The second year focused on developing software to demonstrate a working emissions control decision aid. The DSA aid developed by the end of that year is described in a previous DSA report.[1]

The basic aid design and the algorithms for estimating surveillance quality and information given away have not changed since the release of that document. Those output displays and input commands that were improved during the year covered by the 1978 report are described in the user's manual (reproduced in this document as Appendix A), which was designed to teach the evaluation participants how to use the aid. It discusses the emissions control problems addressed by the

---

[1] G. E. Pugh, D. F. Noble, An Emissions Control Decision Aid, Vol. I, DSA Report No. DSA-66, July 1978.

aid and illustrates all current aid displays and commands. The user's manual provides basic background information for this report and is a good introduction for those unfamiliar with the aid.

1.2 BACKGROUND ON TEST PROGRAM

The independent aid evaluation conducted in the summer of 1979 provided ONR with statistical data on aid quality. Three organizations, each under separate contract to ONR, participated in the aid evaluation: (1) Applied Psychological Services (APS) was responsible for the integrity of the evaluation. They prepared the test design, trained test participants, conducted the tests, analyzed the interpreted data, and reported the results; (2) The Wharton Business School at the University of Pennsylvania maintained the test bed. They were responsible for securing a suitable test environment and maintaining needed hardware support; (3) Decision-Science Applications, Inc. prepared the aid for testing and supported Applied Psychological Services as described in this report. To preserve the complete independence of APS, DSA did not participate directly in the test process itself nor in the interpretation of test data. The APS report[1] summarizes details of the test design, of the participant training program, and of experimental findings. This DSA report concerns only DSA work to prepare the model for testing and to support APS in the testing program.

1.3 REPORT OVERVIEW

During the period covered by this report, DSA modified aid input structure and display formats, conducted initial shakedown tests, developed procedures for EMCON plan design and evaluation, wrote user's manuals for the aid evaluation program, designed EMCON scenarios for these tests, and provided general support for the APS test program. Chapter 2 details aid changes, Chapter 3 describes the scenario development process, and Chapter 4 discusses the user's manuals, which are appended to this report. Neither the shakedown process nor the many DSA support activities warrant full chapter coverage, but both deserve

[1]E. G. Madden, A. I. Siegel, Evaluation of Operational Decision Aids: 2, The Emissions Control Aid, Applied Psychological Services, April 1980.

passing mention here. During the shakedown tests, DSA critiqued existing displays and developed basic procedures for EMCON plan design and evaluation. The products of these shakedown tests are described throughout this report, with aid changes covered in Chapter 2 and EMCON planning processes covered in Chapter 3 and the user's manual. One concept, that of deceptive EMCON plans, deserves special mention here. With such plans, enemy targeting based on the pattern of emissions would often destroy considerably less task force value than would uniform targeting of all task force ships. Chapter 3, which describes the scenario design process, discusses deceptive EMCON plans in more detail.

Besides the major support tasks of preparing user's manuals and test scenarios, DSA supported APS in numerous other ways. DSA and APS worked together to choose the adopted test design--one which controlled for between-subject differences by having the same participants work EMCON problems both with and without the aid. DSA reviewed test debriefing questions, suggested weightings for the aid objectives, and designed the "complexity" component for the difficulty classification of test problems. In addition, DSA instructed APS personnel on the use of the aid, and provided specialized software for expediting the test mechanics. This report does not discuss these many miscellaneous support activities in any detail, but rather concentrates on those major tasks which are most relevant for decision aid design and evaluation.

2.0 MODIFICATIONS TO INPUT COMMANDS AND OUTCOME DISPLAY FORMATS

2.1 COMMAND MODIFICATIONS

There were two principal modifications to command language. First, command key words were changed so that each command better describes the purpose of its associated display. Second, the commands eliciting simulated strikes against the task force were restructured to explicitly differentiate between strikes in which the attacker has complete information and those in which he infers ship identity from the pattern of task force emissions and other possible a priori information.

2.1.1 Command Reorganization

The syntax changes were designed to help aid users to understand the basic logical structure of the aid and to associate displays with their appropriate commands.

The aid command syntax consists of a series of key words--or strings of words--which unambiguously define desired mathematical operations, scenario changes, or output displays. For example, the command to display cumulative probability of detection contours for a specified threat is:

SURV, CUM, THREAT = Threat Name, CENTER = x/y, EXT = z

where "Threat Name" is a threat previously defined by the user, and x, y, and z are input numbers. The first key word, SURV, is the general category of emissions control planning to which the called display belongs, called "surveillance assessment." The second word, CUM, is the desired specific aid feature in that category, cumulative detection probability. The third string is the desired threat, and the fourth and fifth strings (which may be omitted) center and scale the display, respectively.

Before these syntax changes were made, the first key word in output display commands designated display format rather than display function. Thus, commands requesting information in list form began with the word "List" and commands requesting map displays began with the word

"Map". Now, all commands which request aid displays begin with one of four key words designating display function: DISPLAY, for display of data base information; SURVEILLANCE, for displays conveying the quality of radar coverage provided by an emissions control plan; INFO, for displays that estimate the task force information conveyed to an attacker by the plan; and TRADEOFF, for displays that reflect overall plan quality by considering both surveillance quality and information given away. DSA did not change the key words of those commands which initialize or change the basic task force or threat data, because these commands were not available to the test participants.

2.1.2 Commands to Evaluate Damage from Enemy Strikes

The decision aid strike simulator allocates attacker missiles to ships by one of five user-selected procedures: (1) manually, with explicit user-specified targeting; (2) optimally, to destroy maximum task force value with the attacker knowing ship identity; (3) optimally, to destroy task force value with the attacker guessing ship identity; (4) proportional to true ship value or; (5) proportional to the target values inferred by the attacker. Depending on the allocation rule, a strike can (1) evaluate the outcome of a particular prespecified attack (manual allocation); (2) estimate probable task force damage under worst case conditions when the attacker has somehow correctly deduced ship identities and uses his attack resources to maximum advantage (optimal allocation); or (3) estimate damage when the attacker targets to maximize damage but must guess ship identities from the observed pattern of radar emissions (optimal allocation with inferred ship ID's). In emissions control planning, the manually allocated strike projects the outcome for a specific attack under a proposed EMCON plan. The second kind of attack, which optimizes allocations given perfect targeting information, measures EMCON plan surveillance quality. The third kind of attack, which depends both on surveillance effectiveness and on information given away, measures overall EMCON plan effectiveness by trading off surveillance coverage with information given away.

The allocation algorithm used in a strike is specified in the strike definition data base, along with the attacker's weapon choice and potential attack bearings. Before changes were made in the command format, all strikes were called by a command "SVSCORE, strike name." A particular strike name was always implicitly associated with one of the three basic emissions control planning purposes through its allocation mode specification. Because the strike command did not explicitly refer to the allocation mode, and because a user might be unaware of the relationship between allocation mode and emissions control planning purpose, the strike results could mislead the emissions control planner.

The new strike command structure insures that the called strike will serve its intended planning purposes. Strikes may be called using three different key words--SVSCOR, SURV, or TRADEOFF. A strike called by the SVSCOR command allocates missiles as specified in the strike data base. The key words SURV or TRADE override the allocation mode specified in this strike data base. Strikes called by the SURV command allocate missiles "optimally by true ship value." The key word SURV indicates that the output reflects only surveillance quality and not information given away, an interpretation consistent with the strike allocation mode. These results may be interpreted either as a worst case strike or as a measure of surveillance effectiveness. If headed by TRADEOFF, the strike allocation will be "optimal by perceived ship value", and the output will reflect the trade-off between surveillance quality and information given away.

2.2 AID DISPLAY MODIFICATIONS

DSA received useful suggestions on possible display improvements during briefings of earlier versions of the aid. In response to these suggestions, DSA redesigned several displays to make them easier to understand, added one new display to provide required mission-related information, and replaced one display with another, more analytically sound, functional equivalent.

2.2.1 Cumulative Detection Probability - A New Display

The cumulative detection probability contour map (Fig. 2-1) gives the distances from the task force high value unit (HVU) at which a radially directed missile of a specified type has a .3, a .5, and a .9 probability of having been detected. This map summarized the overall quality of the surveillance coverage by highlighting gaps in surveillance coverage that an attacker could exploit, and by showing the expected distances for first detection along the more likely attack paths.

This display replaced the detection rate contour display (Fig. 2-2) as the map summarizing surveillance coverage. The detection rate map plots contours at which the detection probability per second is .005, .02, and .04. The detection rate map has the analytical advantage of being independent of threat speed and direction, and thus in theory should measure surveillance effectiveness against the named missile for an arbitrary course and speed. On the other hand, the new cumulative probability display is correct only for the specified threat at one speed on a radial bearing toward the high value unit. During briefings of the aid, the previously used detection rate map frequently confused the audience when they tried to interpret the display as a measure of task force vulnerability. Apparently users want to know how close a threat can penetrate before being detected, and not its detection rate a given distance from the carrier. Therefore, DSA replaced the display of detection rate with less general but more operationally significant display of cumulative detection probability.

2.2.2 Surveillance Score - A Modification to Increase Display Validity

The emissions control aid contains a single number surveillance score that summarizes the overall quality of surveillance coverage. A properly designed surveillance score should measure the quality of surveillance coverage and should not be sensitive to factors unrelated to radar coverage, such as attacker weapon yield, and CEP, or ship

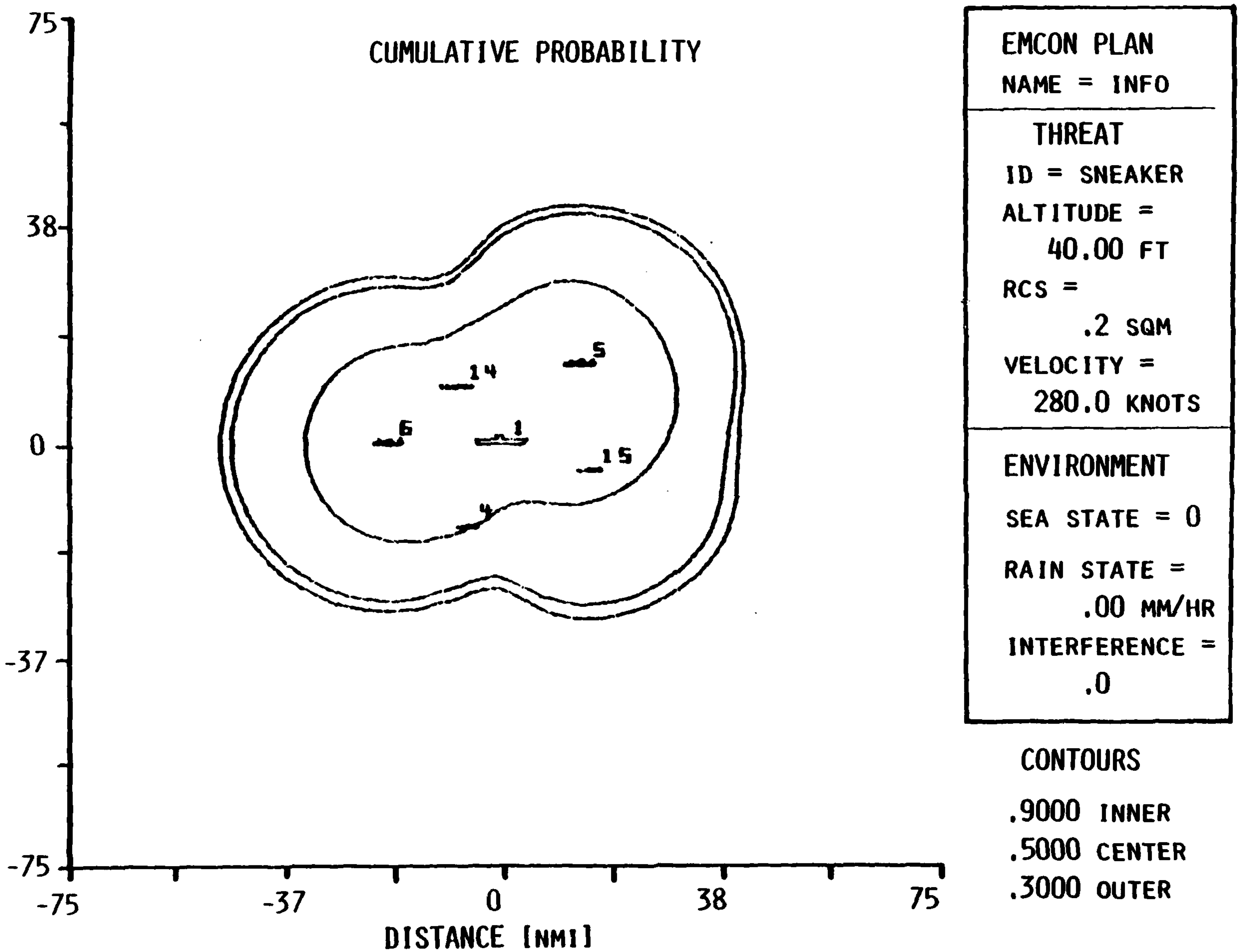


Figure 2-1. Cumulative Detection Probability. This display replaces the detection rate conditions, Figure 2-2.

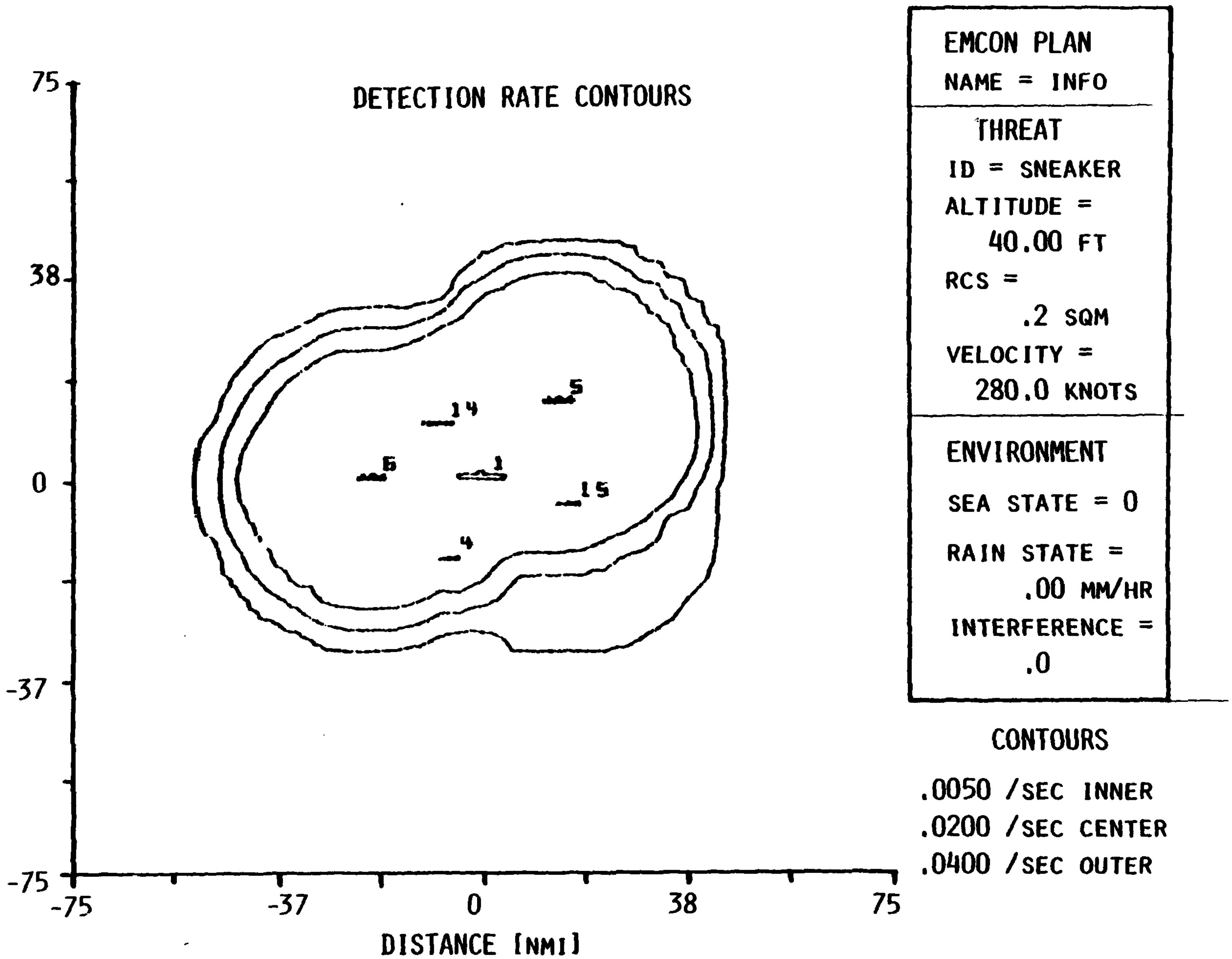


Figure 2-2. Detection Rate Contours

hardness. Further, if the surveillance score is to compare the surveillance quality of alternative EMCON plans fairly, it must use the same scoring methodology for all EMCON plans.

The earlier "surveillance score" was the outcome from a simulated strike. Since the particular strike called (Fig. 2-3) can change during the planning session, a single EMCON plan can have many surveillance scores, each corresponding to a different strike type. In addition, these strike outcomes depend on factors (such as ship hardness and ship damage per hit) which are not directly related to radar coverage. Finally, in those cases where the weapon allocation in the specified strike depends on attack ship ID inferences, the "surveillance" score measures information given away as well as surveillance quality.

The revised surveillance score (Fig. 2-4) measures surveillance quality much more reliably and consistently than did the previously used score. The new score is a weighted average of several surveillance subscores, each of which is the average interception probability of a particular threat type directed against the entire task force. In each subscore the importance of penetration to a particular ship is proportional to ship value. At the beginning of a planning session, the aid user can select the threat types and subscore weights to be used in surveillance score calculation. Thereafter, the surveillance score is computed on this basis for all EMCON plans. In summary, the revised score is a much better measure of surveillance quality than the old one because it compares different EMCON plans consistently, and because it does not depend on factors unrelated to surveillance coverage--factors such as information given away or ship hardness.

2.2.3 Displays Changed to Convey Information More Clearly

These changes recast information previously available in a more easily understood format. Two changes replace tables with graphs, a third change combines information partially available in two places

OPTIMAL STRIKE
ATTACKER KNOWS SHIP IDENTITY

FRACTIONAL VALUE REMAINING = .2/0
STRIKE = SNEAKER
EMCON PLAN = INFO

STRIKE: SNEAKER
EMCON PLAN: INFO

THREAT	SHIP	ALLOCATION	PEN. PROB.	# HITS	FRACTION REMAIN	SHIP VALUE INIT	SHIP VALUE REMAIN
SNEAKER	KITTY HAWK	5	0.995	5.0	0.07	940.0	66.7
	SPRUANCE	10	1.000	1.0	0.31	91.0	27.9
	NASTY	0	--	--	1.	1.0	1.0
	TRUETT	1	1.000	1.0	0.24	48.0	11.7
	CHICAGO	2	0.399	0.6	0.58	203.0	117.3
	OKLAHOMA CITY	1	0.373	0.3	0.77	175.0	134.5
	HOLT HE	0	--	--	1.	48.0	48.0
TOTALS:		10	--	7.8	--	1506.0	407.1

Figure 2-3. Task Force Value Surviving a Simulated Strike. These strikes served as "surveillance scores" in early aid versions.

EMCON PLAN = INFO

SURVEILLANCE SCORE-----INTERCEPTION PROBABILITIES

THREAT NAME	INTERCEPTION PROBABILITY CURRENT PLAN	INTERCEPTION PROBABILITY ALL ON	WEIGHT
SNEAKER	.23	.72	.5Ø
STREAKER	.5Ø	.63	.5Ø
SCORE	.36	.68	

Figure 2-4. Surveillance Score in Current Aid

within a single summarizing display, and the fourth change helps to identify important ships in the map displays.

2.2.3.1 Emissions Control Matrix - Reorganization of Tabular Information Into a Matrix Format

Earlier versions of the aid summarized task force radar status in a table (Fig. 2-5). A naval officer reviewing the aid suggested recasting this information in the matrix format shown in Fig. 2-6. In this latter figure, radar types are listed along the top margin and ship types in a column at the left. A box with a solid "x" indicates that a radar of that type is on a particular ship and is active; a box with a dotted "x" indicates that a radar of that type is aboard the ship but is not emitting; and a box with no "x" indicates that a radar of this type is not on this ship.

Changing the EMCON plan display proved to be a most important revision to the aid. Rearranging the radar order of battle in matrix format led to the development of the emissions control planning procedures discussed in the next chapter. Had the information not been available in this format, development of these procedures would no doubt have required much more time.

2.2.3.2 Targeting Value Display - Replacement of Table with Graphs

Figures 2-7 and 2-8 compare tabular and graphical displays which summarize attacker inferences of ship values. The current graphical representation of these perceptions (Fig. 2-8) summarizes the targeting information inferred from an EMCON plan much more clearly than does the previously used tabular display (Fig. 2-7). For this use, the graph is more effective than the table. Since targeting decisions do not require the table's numerical precision, this detail only clutters and distracts. On the other hand, the relative line lengths in the graph relate directly to the number of attackers that might be targeted against each ship, and the pattern of these line lengths suggests the degree of enemy targeting confusion.

CHICAGO			
OFF:	SPS-48	ON:	SPS-1Ø
ON:	SPS-52	ON:	SPS-3Ø
ON:	SPS-43		
GRIDLEY			
OFF:	SPS-48	ON:	SPS-1Ø
ON:	SPS-43	OFF:	SPS-37
TRUETT			
ON:	SPS-1Ø	OFF:	SPS-4Ø
PONCHATOULA			
ON:	SPS-1Ø		
OKLAHOMA CITY			
ON:	SPS-1Ø	ON:	SPS-52
ON:	SPS-3Ø	ON:	SPS-43
KITTY HAWK			
OFF:	SPS-3Ø	ON:	SPS-1Ø
OFF:	SPS-43	OFF:	SPS-52

Figure 2-5. Radar Status for EMCON Plan INFO as Displayed in Earlier Versions of Aid. Information on this display is represented in matrix form in Fig. 2-6.

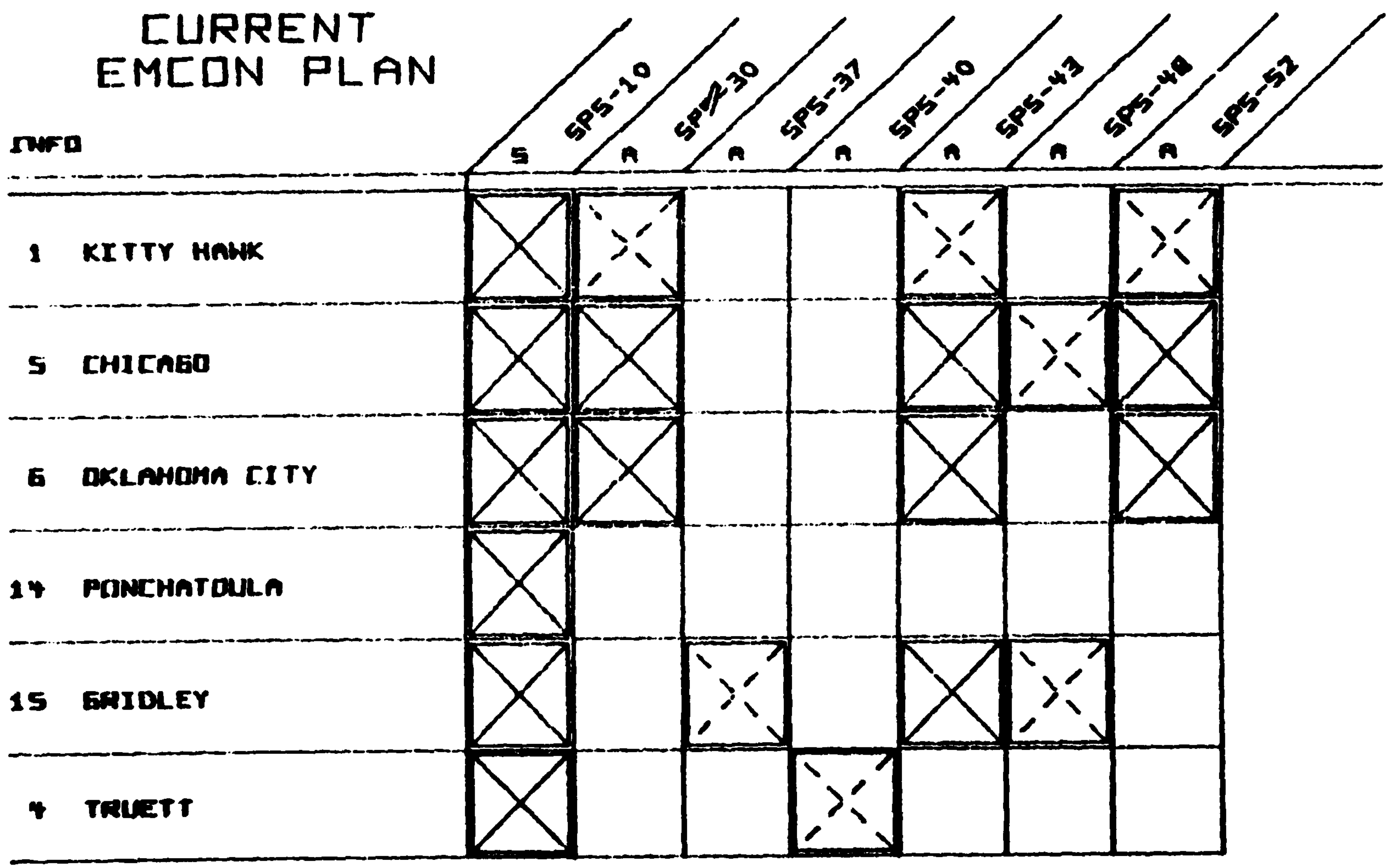


Figure 2-6. Radar Status for EMCON plan INFO as Displayed in Current Version of Aid

SHIP NAME	ASSIGNED VALUE	PERCEIVED VALUE	PROBABILITY OF CURRENT ID SIDE	TYPE	CLASS	SHIP
Kitty Hawk	940.	162	1.00	0.06	0.06	0.06
Truett	48.	162	1.00	0.5	0.33	0.33
Chicago	203	450	1.00	0.67	0.33	0.33
Oklahoma City	175	450	1.00	0.67	0.33	0.33
Ponchatoula	175	162	1.00	0.33	0.33	0.33
Gridley	90	245	1.00	0.5	0.5	0.5

Figure 2-7. Targeting Values as Displayed in Earlier Aid Versions. Probability of correct ID included attacker perceptions of target values.

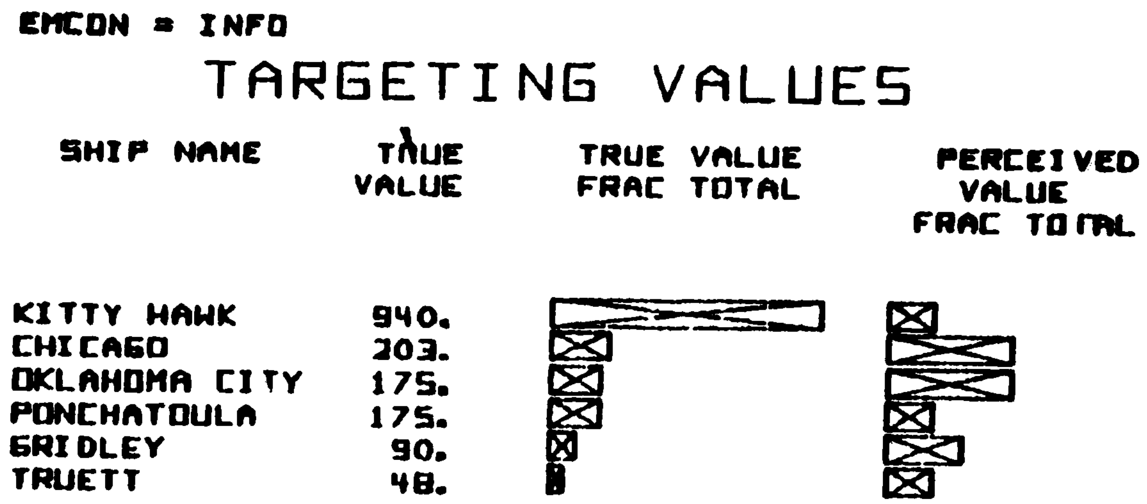


Figure 2-8. Actual Ship Value and Perceived Blip Value Compared

The part of Fig. 2-7 summarizing probabilities of correct ship identification is currently available in a separate tabular display.

2.2.3.3 Trade-Off Map - A New Display Summarizing Information and Surveillance

The "Trade-off" map (Fig. 2-9) combines the contours from the cumulative probability display with information about attacker perceptions from the targeting values display. In the trade-off display, ship length is proportional to ship value, while the length of the line drawn beneath each ship is proportional to perceived ship value. The intent of the display is to suggest, in a single figure, both enemy targeting capability and defense quality against this targeting. Unlike the other recently developed displays, this particular display was not thought helpful by the participants in the formal test evaluation.

2.2.3.4 Development of New Ship Symbols - An Aid to Identify Important Ships

In the earlier versions, displays having maps of ship position identified each ship by an arrow (↑) followed by a ship identification number. Since most of these displays did not include a legend relating identification number to ship name, a user new to the aid would need to look up this information on a separate chart. The new ship symbols (Fig. 2-10) identify important ships both by symbol sign and by symbol shape. Symbol size is proportional to the cube root of value (except in the trade-off map), and symbol shape denotes ship type. Thus, in the current aid, the display maps highlight the high valued units, and allow the user to locate these ships without looking up their numbers.

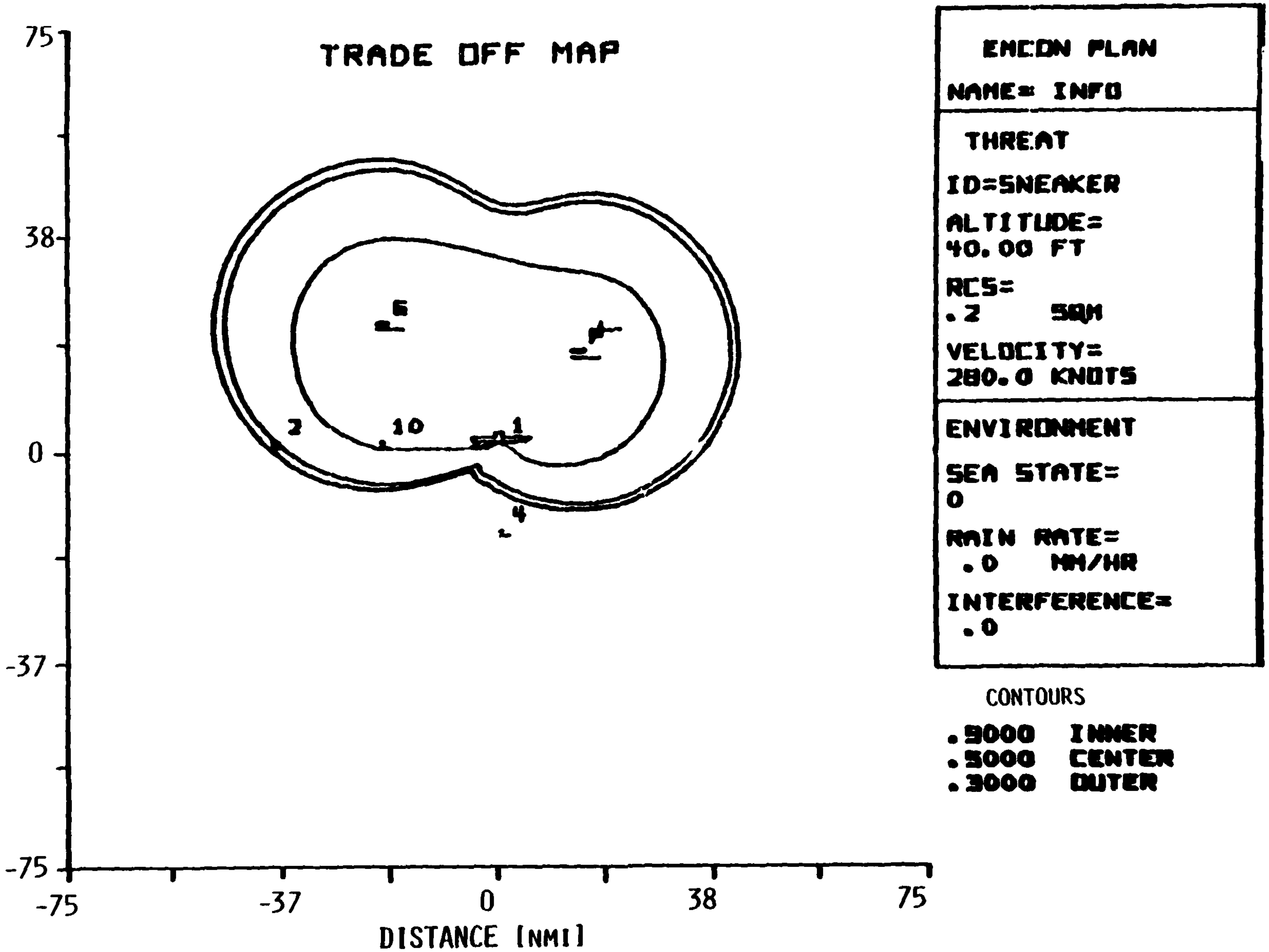


Figure 2-9. Trade-Off Map, a Display Conveying Information about Enemy Penetration Capability and Targeting Inferences.

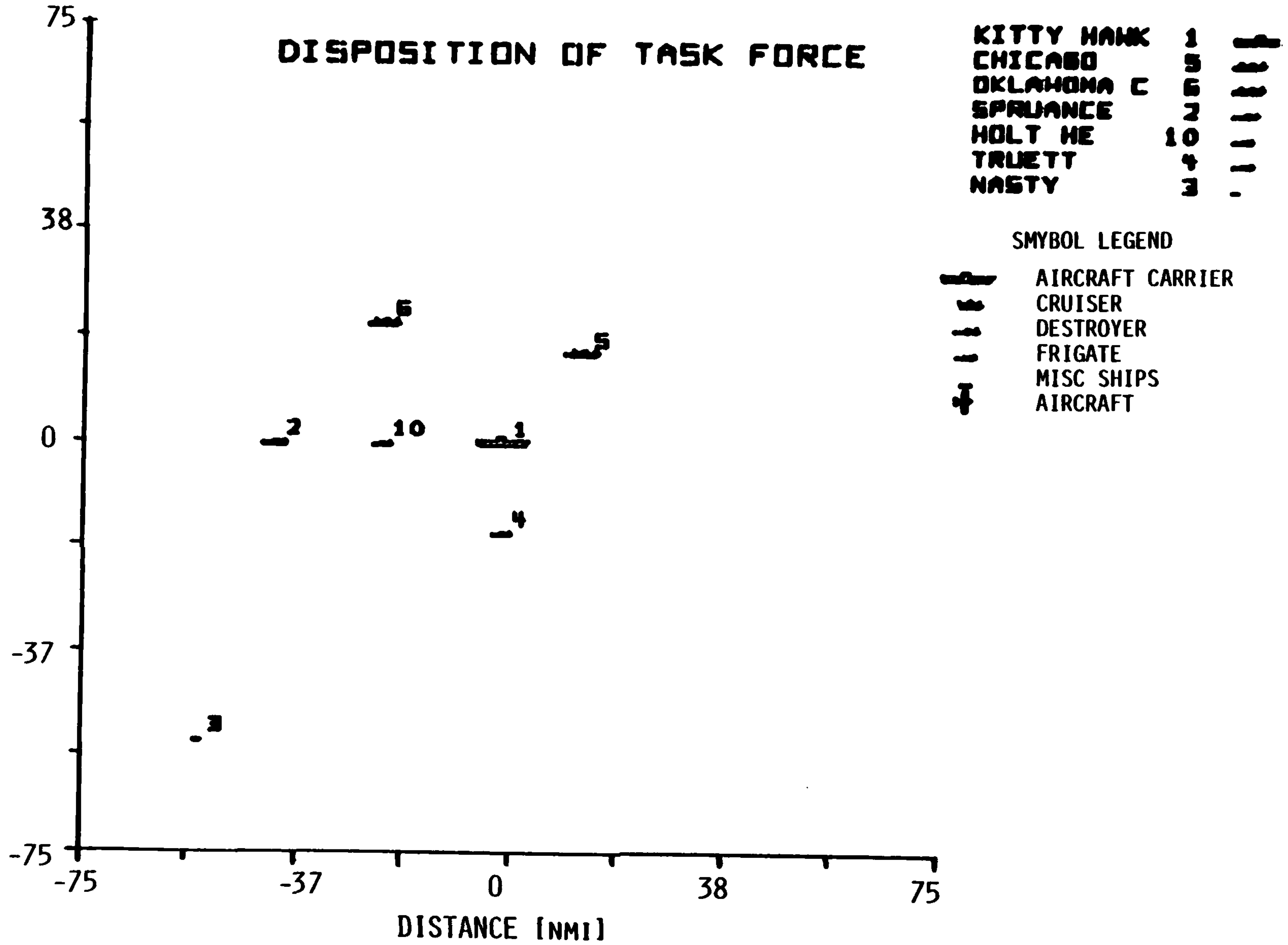


Figure 2-10. Disposition of Task Force Indicating Symbol Types Used in the Current Display

3.0 DEVELOPMENT OF SCENARIOS TO SUPPORT FORMAL AID EVALUATION

To support the formal aid evaluation, DSA developed fifteen candidate scenarios in which emissions control posture impacted task force survivability. This scenario development required first the definition of an appropriate general operational environment, and then the construction within this environment of a set of specific scenarios, each defined by task force configurations. The scenario set developed by the process described here reflects the specific needs of a formal aid evaluation, and are not intended to represent a typical cross section of task force configurations.

To satisfy test program requirements, the set of configurations should satisfy three criteria. First, for each configuration task force survivability (a principal measure of effectiveness in these tests) should be reasonably sensitive to changes in EMCON plan. Otherwise, if survivability did not depend on EMCON choice, plans selected without an aid would necessarily be as good as plans selected using the aid. Second, the same basic EMCON plan should not suffice for all configurations. Rather, survivability in different configurations should be promoted best by different plan types. Otherwise, during the aid evaluation, participants could successfully apply plans developed previously (with the aid) to new configurations for which EMCON plans are to be developed without using the aid. Third, the set of configurations should generate problems with a broad range of difficulty. Otherwise, there is a chance that all problems either would be too easy to require the aid or too hard to be analyzed within the allotted testing period.

To design scenarios that meet these criteria, DSA selected an appropriate basic scenario, identified several basic classes of EMCON plans, identified those aspects in a scenario that would favor adoption of each kind of EMCON plan, developed and evaluated fifteen specific scenarios, and recommended which of these scenarios should be used for testing, which should be used for instruction, and which should be discarded.

3.1 BASIC TEST SCENARIOS

Enemy resources, a priori targeting information, attack doctrine, and own force doctrine define the basic test scenario. For the aid evaluation scenarios, intelligence has identified the enemy threat relevant for current EMCON planning. The enemy knows the task force composition and radar order of battle, has blip enhanced radar returns indicating which ocean locations contain U.S. Navy ships, and can associate with each return return electromagnetic sensing measurement (ESM) data that identifies by type all emitting radars. The enemy does not know the identity of ships at these locations, but must infer ship identity from the pattern of task force emissions. Enemy targeting effectiveness is likely to depend on the quality of these inferences.

The task force commander wants to be prepared for a possible surprise attack, and desires an emissions control posture which maximizes task force survivability by denying useful targeting information and by providing as much attack early warning as possible. The task force has no decoys or vans to mimic radars on high value ships. The task force commander has determined the positions of task force ships, and has decided against augmenting shipboard air search radars with an airborne early warning radar. The EW officer is to recommend an appropriate emissions control posture, but should not explore benefits from changing force configuration or from launching early warning aircraft.

The fifteen scenarios developed by DSA share the assumptions described above, but differ in the numbers, types, and placement of task force ships.

3.2 BASIC EMISSIONS CONTROL PLANS

The four basic emissions control postures relevant to this text environment are maximum surveillance, maximum deception, maximum deception augmented by radars on the high value unit (HVU), and maximum deceptions augmented by radars not on the high value unit.

These representative EMCON postures help structure the scenario design process to insure that different scenarios are optimized by different kinds of plans.

3.2.1 Maximum Surveillance Posture (Plan ALL ON)

Maximum surveillance provides maximum interception capability and, if the enemy knows the location of the most valuable ships, best survivability. Since it also reveals the most targeting information, plan ALL ON may not be the best plan when the enemy does not already know the location of the more valuable task force ships.

3.2.2 Maximum Deception Posture (Plan INFO)

Plan INFO is obtained by setting emitter status as specified by the following three rules: (1) turn off all radars on the HVU unless this radar type is aboard every task force ship; (2) on the other task force ships, turn on all radars of a type also aboard the HVU; (3) on these task force ships (not HVU), turn off all radars of a type not on the HVU.

This plan minimizes the useful targeting information conveyed by an EMCON plan, given the basic enemy a priori knowledge assumed in these scenarios, and is often a deceptive plan. Such a plan presents the attacker with a dilemma, for if he attempts to use the pattern of radar emissions for targeting, he may be seriously misled, while if he chooses not to use this information, he can target no better than randomly. Examining how an attacker may infer ship ID's from the pattern of radar emissions may explain why EMCON plans obtained from these three rules are deceptive, and also may suggest why plan INFO is more effective for some task forces than for others.

To infer the HVU location, the attacker examines each ESM source in turn, and estimates its probability for being the HVU. First, he eliminates ESM sources that cannot be the HVU because they include

a signature for a radar not on the HVU. If there are n ESM sources compatible with the HVU radars, each of these is tentatively assigned a $\frac{1}{n}$ probability of being the HVU. Next, the attacker considers what other ships are compatible with each ESM source. An ESM source that could be many ships other than the HVU is thought less likely to be the HVU than an ESM source that could be, e.g., only the carrier and one other ship. Therefore, the HVU probability for an ESM source compatible with few ships is increased; the HVU probability for an ESM source compatible with many ships is decreased. Third, the attacker examines in more detail the other ships tentatively assigned to each ESM source with the HVU. If one of these other ships can be assigned to only two or three ESM sources while the HVU could be assigned to many, then each ESM source compatible with this ship would have a higher probability of being that ship than it has of being the HVU assignable many more places. Thus, sharing an ESM source with a hard to place ship reduces the probability that this source is the HVU.

Plan INFO is effective because it exploits all three of these rules: it insures that the HVU is compatible with all ESM sources, that all task force ships can be assigned to the carrier ESM source, and that some ships assignable to the HVU ESM source are relatively hard to assign elsewhere. Rule 1, turning off all HVU radars not on every ship, insures that all TF ships are compatible with the HVU ESM source. Rules 2 and 3, turning on only radars that are on the HVU, insures that the HVU can logically be assigned to all ESM sources. And rule 2, turning on HVU type radars aboard other ships, limits the placement of some ships to just the HVU ESM source and a few others, thereby increasing the inferred probability that the HVU ESM source must be one of these other ships.

3.2.3 Maximum Deception Posture Augmented by Other Radars on the HVU

Frequently the maximum deception EMCON plan leaves radar coverage gaps and cannot provide adequate early warning of surprise attack.

In that case, the overall quality of the EMCON plan may be improved by increasing the radar coverage. Turning on an additional HVU radar decreases risks that an enemy strike will penetrate the task force and HVU defense, but will improve enemy targeting capability. Each additional emitting HVU radar limits the number of ships that can be assigned to the HVU ESM source, thereby increasing the attacker-computed probability that the HVU ESM source actually corresponds to the HVU.

Both the survivability increase from the added radar coverage and the decrease from improved attacker targeting depend on the task force configuration. If activating another HVU radar does not significantly decrease the number of ships assignable to the HVU ESM source, but fills a gap in surveillance coverage, the change may be beneficial. If, on the other hand, such activation significantly limits the number of ships assignable to this ESM source and adds little to the radar coverage, the resulting EMCON plan quality may be reduced.

3.2.4 Maximum Deception Posture Augmented by Radars on Other TF Ships (INFO + Non HVU)

Usually when plan INFO radar coverage is inadequate, the plan can best be improved by turning on additional radars aboard HVU support ships. Since turning on extra radars aboard these ships reduces the number of ESM sources to which the HVU can logically be assigned, turning on such radars improves attacker targeting. The overall effect from turning on these radars depends on the quality of the added radar coverage, the need for this coverage, and the number of ESM sources that could still be regarded as potential HVUs.

3.3 CONSTRUCTION OF CANDIDATE SCENARIOS

Design of the candidate scenarios proceeded in three steps. First, those aspects of task force configuration that correlate with a need for each of the four EMCON classes described above were identified. Second, DSA designed a balanced set of task force configuration

"blueprints" which reflect these different factors; and third, the configuration "blueprints" were converted to actual scenarios with specific ships at appropriate locations.

3.3.1 Task Force Features that Influence EMCON Plan Choice

These features include the number of high value ships, the number of ships with air search radars of a type that are on the HVUs, the number of ships with other types of air search radar, the number of ships with no air search radars, and the spacing of these ships.

3.3.1.1 Number of High Value Units

In these scenarios, high value ships are aircraft carriers. Other ships in the task force, which are included primarily to protect and service the carriers, have lower values. The aid default for ship value--normalized tonnage--reflects the critical contribution of the carrier to the task force mission. The default value of a PT boat is about one; of a destroyer, about 100; of a cruiser, about 250; and of a carrier, approximately 1000.

Denying information is most important when the distribution of ship values within the task force is broad. A task force in which every ship has the same value cannot increase surviving task force value with a deceptive EMCON plan because the attacker knows that each ESM sourc s the same value no matter which ship the source happens to be. For such "equal value" task forces, the optimum EMCON plan would be ALL ON in these scenarios. On the other hand, denying information is most important when there is only one target worth hitting, and when the attacker has just a few very capable missiles. In this case, denying information is critical because missiles must be decoyed from the HVU if it is to escape serious damage.

Most candidate task force configurations contain one HVU. These tend to fare best with deceptive EMCON plans. A few candidate configurations have two carriers. These may do better with plans emphasizing surveillance coverage rather than deception.

3.3.1.2 Number of Ships Having Air Search Radars of a Type on the HVU

These ships increase the likelihood that plan INFO, the high deception EMCON plan, will provide best task force protection. Since under plan INFO all radars of a type on the HVU are emitting, each of these ships provides air search coverage without giving away any useful ship identification information. If such coverage is adequate, plan INFO needs no additional surveillance coverage. On the other hand, if the task force does not have such ships, or has them spaced far from the carrier, then plan INFO may not provide adequate air surveillance coverage.

3.3.1.3 Number of Ships Having Air Search Radars, None of Which are of a Type Aboard the HVU

Each of these ships may function primarily as an HVU decoy or as a provider of radar coverage. When their "non-HVU" radars are inactive, these ships may be mistaken for the HVU. When these radars are active, the ships no longer will be identified as a potential HVU, but surveillance quality may be much improved. The overall effect of turning on a radar aboard one of these ships depends on the total number of ships available as potential HVU decoys, on the quality of surveillance in plan INFO, and on the potential improvement in surveillance from activating these radars.

3.3.1.4 Numbers of Ships with No Air Search Radars

In EMCON planning, non-radar ships serve only as potential HVU decoys. Increasing the numbers of these ships increases the likelihood that plan INFO can be improved by activating radars on other ships since, as the total number of potential decoys increases, the penalty from identifying each as a non-HVU decreases.

3.3.1.5 Task Force Spacing

The disposition of task force ships strongly affects radar coverage, but has no affect on information given away by an EMCON posture. Radars

on ships close to the HVU supplement HVU radars in detecting air threats, while those on ships further away detect only those HVU-directed missiles which pass nearby. Spacing is most important for low-altitude threats where radar detection range is horizon-limited.

3.3.2 A Balanced Set of Blueprints for Candidate Task Force Configurations

Table 3-1 lists the "blueprints" for the set of candidate task force configurations. Each scenario is described in terms of the five factors described above; the number of high value units, the number of other ships with radars of a type on the HVU, the number of ships with radars of a type not on the HVU, the number of ships with no air search radars, and the spacing of ships. These scenario blueprints specify spacing only of ships with HVU type radars because only these ships affect the surveillance quality in plan INFO.

A set of task force configuration scenarios designed from this blueprint hopefully will include task forces whose survivabilities are maximized by EMCON plan representing all four basic classes. Ideally, some of these configurations will fare best with a maximally deceptive EMCON plan ("INFO"), some with plan ALL ON, some with INFO augmented by other radars on the HVU, and some with INFO augmented by radars not on the HVU.

3.3.3 Construction of Candidate Scenarios

Table 3-2 lists the ships available for the test scenarios, their values, and radar types aboard each ship. Twelve scenarios contain either the Kitty Hawk or Forrestal and three include both carriers. Both carriers have air search radars SPS-30 and SPS-43. The Kitty Hawk also has an SPS-52. Ships having these types of air search radars--the Chicago, the Oklahoma City, the Tarawa and the Gridley--can fill the role of "others with radars on HVU" in the scenario set blueprint. Four ships--the Ponchatoula, the Vireo, the Widgeon, and the Nasty--

TABLE 3-1

BLUEPRINT FOR BALANCED SCENARIO DESIGN SET

12 Scenarios with 1 HVU

3 Scenarios without any low value ships equipped with HVU-type radars

	Scenario Number
10 * 50	(6)
10 * 51	(7)
10 * 21	(11)
3 Scenarios with one low value ship equipped	
11 C 31	(1)
11 A 30	(8)
11 C 32	(9)
4 Scenarios with two low value ships equipped with HVU-type radars	
12 B 01	(2)
12 A 13	(10)
12 C 40	(12)
12 B 31	(3)
2 Scenarios with three low value ships equipped with HVU-type radars	
13 B 11	(13)
13 B 22	(14)
3 Scenarios with 2 HVU	
23 B 00	(4)
23 B 30	(5)
20 * 22	(15)

CODE: k ℓ x m n

k = # HVU
ℓ = # others equipped with HVU-type radars
x = A if ℓ's close, B if intermediate, C if far
m = # ships equipped with air search radars but none of a type aboard HVU
n = # of other ships

EXAMPLE: 12A13 = 7-ship task force composed of 1 HVU, 2 low value ships equipped with HVU-type radars, 1 low value ship equipped with air search radars none of which are a type aboard the HVU, and 3 ships with no air search radars.

A SCENARIO SET THAT FOLLOWS THIS BLUEPRINT WILL CONTAIN A VARIETY OF DIFFERENT TASK FORCE CONFIGURATIONS ASSOCIATED WITH A VARIETY OF DESIRABLE EMCON PLANS

TABLE 3-2

SHIPS AVAILABLE FOR AID SCENARIOS

	VALUE	TYPE	10	55	30	40	29	43	48	52	37	39
								Search Radars				
1 Kitty Hawk	940	Carrier	✓		✓			✓		✓		
21 Forrestal	906	Carrier	✓		✓			✓				
16 Tarawa	456	Amphibious	✓			✓				✓		
20 Blue Ridge	198	Amphibious	✓			✓		✓				
5 Chicago	203	Cruiser	✓		✓			✓	✓	✓		
6 Oklahoma City	175	Cruiser	✓		✓			✓		✓		
2 Spruance	91	Destroyer		✓		✓						
8 Foster PF	91			✓		✓						
19 Cochrane	52		✓			✓	✓				✓	✓
12 Fiske	41		✓			✓	✓				✓	
17 Higbee	41		✓			✓	✓				✓	
5 Gridley	90	Frigate	✓					✓	✓		✓	
4 Truett	48		✓			✓						
9 Bowen	48		✓			✓						
10 Holt HE	48		✓			✓						
11 Roark	48		✓			✓						
13 Garcia	40		✓			✓						
14 Ponchatoula	175	Auxiliary	✓									
7 Vireo	4	Mine Sweeper	✓									
8 Widgeon	4		✓									
3 Nasty	1	PT	✓									

have no air search radars. Because these ships provide no surveillance coverage, their positioning does not affect EMCON plan choice in these scenarios. The remaining ships in Table 3-2 have air search radars of a type not on the HVU.

Table C-1 in Appendix C lists ships chosen for each scenario, and Figs. C-1 to C-15 display the positions of these ships. Within the constraints of the blueprint specification, these configurations are somewhat arbitrary; they were selected to provide variety in ship types and in geometry.

3.4 FINAL SELECTION OF SCENARIOS

Of the fifteen candidate scenarios, eight were recommended to be test problems in the aid evaluation, three to support subject training, and four to be discarded. Criteria for scenario selection included sensitivity of task force survivability to EMCON plan choice; whether the EMCON plan best for this scenario adds to variety in the total set; and whether a plan contributes to achieving the desired range of scenario difficulty.

3.4.1 Sensitivity of EMCON Plan Choice to Task Force Survivability

For each scenario, DSA evaluated task force survivability for four EMCON plans--plan INFO (the maximum deception plan), ALL ON, an "INFO augmented by a HVU radar," and an "INFO augmented by radars on other ships." The two augmented INFO plans represent good plans in these two classes of EMCON postures, but were not necessarily the best possible plans in these classes. Task force survivability was estimated using the aid's TRADEOFF, STRIKE--a simulated optimized attack with the attacker inferring target value from the pattern of radar emissions.

Table 3-3 lists the outcomes for each candidate EMCON plan. Generally an EMCON plan with INFO augmented by a radar not on an HVU was best. Plan ALL ON was never best; a plan with INFO augmented by

an HVU radar was preferred in one case; and plan INFO worked best in the remaining cases. Because the greatest sensitivity to EMCON plan choice occurred with task force survivability optimized when INFO is augmented by radars not on the HVU, most scenarios selected for the test program were those in which optimum survivability resulted from development of such an EMCON plan.

3.4.2 Scenario Difficulty

Applied Psychological Services recommended three measures of scenario difficulty: the number of ships in the scenario, the number of different potential EMCON plans, and the number of different threat types.

3.4.2.1 Calculation of Complexity Figure of Merit

The "complexity" figure in Table 3-3 is a measure of the number of possible EMCON plans. It is computed as follows: on the EMCON display chart (Fig. 2-6) pick a column. Find another column in which the radar order of battle differs from this as little as possible. Add the number of differences between those columns. Choose a third column that differs from either the first or second columns as little as possible. Add to the difference between column one and two the lesser of the differences between this third column and the first or second. Continue this process for all columns and repeat for the set of rows. The total of these differences is the complexity score.

3.4.2.2 Number of Threat Types in Scenario

Scenario difficulty is increased when the planner must consider several different threat types, each requiring a different EMCON posture. In some of these scenarios the test participant must consider two threat types and in some only one. Since two threat types complicate EMCON planning most when each threat type requires a different kind of EMCON plan, DSA developed a "conflict index" to measure the sensitivity of EMCON plan choice to threat type. This index is the

TABLE 3-3

SUMMARY OF SCENARIO CONDITIONS

Scenario	Description Code*	Status	Recommendation # Threats	Recommendation Difficulty	Difficulty Complexity	Difficulty # Ships	Plan Outcome INFO	Plan Outcome HVU	Plan Outcome Not HVU	Plan Outcome ALL ON	Conflict Index
1	11C31	TEACH	-	-	154	6	0.5	0.42	0.48	Not Eval.	0.98
2	12B01	TEACH	-	-	28	4	0.52	0.5	Not Eval.	Not Eval.	Not Eval.
3	12B31	TEST	1	Easy	56	7	0.66	0.6	$\boxed{0.76}$	Not Eval.	Not Eval.
4	23B00	DISCARD	-	-	30	5	0.65	0.56	0.62	0.54	1
5	23B30	DISCARD	-	-	104	8	0.68	0.63	0.67	0.54	0.93
6	10*50	DISCARD	-	-	48	6	0.44	0.32	0.43	0.37	1
7	10*51	TEST	2	Hard	80	7	0.46	0.34	$\boxed{0.62}$	0.39	0.8
8	11A30	TEACH	-	-	80	5	0.61	0.43	0.78	0.4	0.97
9	11C32	TEST	2	Hard	88	7	0.56	0.42	$\boxed{0.73}$	0.41	0.747
10	12A13	TEST	2	Hard	100	7	$\boxed{0.72}$	46	0.69	0.36	0.91
11	10*21	TEST	2	Easy	30	4	0.33	0.33	$\boxed{0.65}$	0.40	0.819
12	12C40	TEST	1	Hard	169	7	0.58	0.46	$\boxed{0.74}$	0.52	1
13	13B11	TEST	1	Easy	72	6	$\boxed{0.69}$	0.54	0.64	0.54	1
14	13B22	DISCARD	-	-	143	8	0.62	0.51	0.71	0.48	1
15	20*30	TEST	1	Easy	32	5	0.34	$\boxed{0.48}$	0.37	0.42	1

*Code k l α m n

k = # HVU
l = # Others with SPS-43
α = A if l's close, B if intermediate,
C if far
m = # ships with air search not on HVU
n = # ships no air search

ratio of task force value surviving an attack by a "low slow" threat under the EMCON plan optimized for a "high fast" threat to task force surviving an attack by the "low slow" threat for the EMCON plan optimized against this threat. For example, in Table 3-4 plan A optimized against "low slow" and plan B against "high fast". As calculated in Table 3-4, the conflict index is .87.

TABLE 3-4

COMPUTATION OF CONFLICT INDEX

	LOW SLOW	HIGH FAST
Plan A	.75	.65
Plan B	.65	.68

Table 3-4 entries are task force survivability for two EMCON plans against two potential missile threats. Plan B is best against the "high fast" threat. The ratio of the outcome against "low slow" for plan B to the outcome against "low slow" for the plan most appropriate to "low slow" is

.65/.75 = .87

If plan A were best against both threats, the index would be, for example, .75/.75 = 1.

In only four of the fifteen candidate scenarios did the threat type significantly impact EMCON plan choice. DSA recommended that these four scenarios include two threat types, and that the others include only one threat type.

3.4.3 Final Selection of Scenarios

Table 3-3 summarizes the scenario selection "criteria". For each of the fifteen candidate scenarios, it specifies its recommended role in the test program, its complexity index, its sensitivity to EMCON plan choice and its conflict index. For each of the eight scenarios recommended as test problems, it suggests the number of threats to be used and whether that scenario should be classified as hard or easy.

The final selection of scenarios to be used in the test program was the responsibility of APS. The careful analysis for scenario construction outlined in these sections provided quality suitable for the formal aid evaluation.

4.0 PREPARATION OF USER'S MANUALS

DSA prepared two user's manuals, one describing the emissions control decision aid and its use to design and evaluate EMCON plans, and a second outlining procedures for comparable plan evaluation without the aid. These manuals are the primary support documents for the formal aid evaluation, and are reproduced in Appendices A and B.

4.1 MANUAL FOR TEST SUBJECTS USING THE ELECTRONIC WARFARE (EWAR) DECISION AID

This manual describes the formal test scenario, surveys and interprets EWAR displays available to test participants, and explains how to use the aid in the design and evaluation of emissions control plans.

DSA planned this manual to be both complete and brief. Completeness is important because the manual was the principal document for teaching test subjects how to use the aid. Brevity is also very important, for an overlong document would discourage the subjects from reading the entire manual and would tend to mask essential information with unimportant details.

4.2 PROCEDURE FOR MANUAL EMCON EVALUATION

The second DSA document to support the aid evaluation outlines procedures for estimating aid outcomes manually. This document was prepared to increase the fairness of the test, to answer questions about aid algorithms, and to represent the kinds of aids currently used in EMCON planning. It increases the fairness of the test by allowing test participants to duplicate the aid estimates for surveillance quality and information given away during unaided sessions. Because the tests use aid outcome measures as estimates of plan quality, a fair test requires that these measures be available even when the aid is not.

Explaining aid algorithms to test participants is another important function of this document. During training for the tests, several participants wanted to know more about how the aid computes surveillance quality and information given away. Although this background information was not part of the manual which described the use of the aid, it is available in the document for manual evaluation.

The third purpose of this document is to represent the current generation of task force decision aids. The current principal support document for emissions control planning (NWP 33-1) contains tables and specialized slide rules for calculating basic surveillance ranges, as well as ship identification information on an emitter-by-emitter basis. The DSA test support document includes such information, and in addition provides formulas and charts so that surveillance and information given away can be computed for the set of emitters acting as a group; thus, these factors can be balanced in a trade-off analysis calculating task force survivability. In these tests, participants did not calculate outcomes using these algorithms--an observation suggesting that an aid which extends NWP 33-1 like EWAR does should be computer-based rather than contained in printed tables.

APPENDIX A

MANUAL FOR TEST SUBJECTS
USING THE ELECTRONIC WARFARE (EWAR) DECISION AID

DSA Report No. 126/1

MANUAL FOR TEST SUBJECTS USING THE ELECTRONIC WARFARE (EWAR) DECISION AID

D. F. Noble
M. T. Nunenkamp

prepared under contract N00014-77-C-0322
for the Office of Naval Research

March 28, 1979

DECISION-SCIENCE APPLICATIONS, INC.
1500 WILSON BOULEVARD, SUITE 810, ARLINGTON, VIRGINIA 22209

CONTENTS

FIGURES

FIGURES
(CONT'D.)

1.0 INTRODUCTION

1.1 PURPOSE

Test subjects participating in the University of Pennsylvania effectiveness tests will use the Electronic Warfare (EWAR) decision aid to develop emission control (EMCON) plans. The purpose of this manual is to define the EMCON problem and to provide a description of the EWAR decision aid sufficient to enable the test subjects to use the aid in developing these plans. Only those parts of the aid that are relevant to the tests and to the simplified scenario presented are described in this manual.

1.2 BACKGROUND

A naval task force must routinely exercise control over the signals radiated by its radar, sonar, and communications systems. Such emissions can be used by potential enemies to obtain information about task force location and activities. The procedures used to limit and control undesirable emissions are known as EMCON (Emission Control) procedures.

The development of EMCON plans involves a difficult trade-off. Information that potentially might be given away to an enemy must be weighed against reductions in task force operating efficiency that can result when certain radars, sonars, and communications equipment are turned off to comply with EMCON restrictions. The EWAR system is a research prototype that has been developed to explore the value of computerized aids in the development of EMCON plans for a naval task force. The EWAR decision aid is designed to assist planners by providing a more quantitative representation of the information given away when emitting systems are turned on, and the degradation in operating effectiveness that can result when these systems are turned off. Because these two considerations--information given away and operating effectiveness--are so different in nature, planners can find it difficult to select an appropriate balance even when both aspects of the problem are rather well understood. Consequently, the EWAR aid has also been designed to provide planners with some assistance in weighing the relative importance of these two considerations.

Actual EMCON procedures change so rapidly with technology, and involve so many detailed and specialized interactions, that it is impractical to incorporate all aspects of the problem in a computerized aid. The EWAR decision aid has therefore been designed to focus on certain key aspects of the EMCON problem that seem to be common to many different task force missions and scenarios. In the development of actual plans, many factors must be considered that cannot be addressed by a standardized decision aid; thus, the output from the EWAR aid must be viewed only as an input to the planner's decision process, and not as an ultimate criterion of decision.

The description of the EWAR decision aid in this manual is limited to those features that are likely to be needed by test subjects in dealing with the test scenarios. In order to provide problems that can be addressed by subjects who are not trained in electronic warfare, and who do not have access to classified defense information, these scenarios and associated EMCON problems have been radically simplified, relative to real operational problems. The test problems, however, are structurally similar to those faced in operational EMCON planning; and information developed in the test concerning the value of a decision aid is expected to be indicative of the potential value of such an aid in the operational environment.

1.3 THE SCENARIO*

A naval task force composed of an aircraft carrier (the Kitty Hawk), a cruiser (the Chicago), a frigate (the Gridley), and a minesweeper (the Vireo) is "showing the flag" somewhere in the Near East. Figure 1 below shows the task force and its deployment.

The task force commander is concerned about the possibility of an air attack directed at his ships. Such an attack would consist of enemy cruise missiles launched from aircraft outside the detection range of task force radars. Intelligence information indicates that as many as 10 cruise missiles would be available for enemy use against task force ships, and that these cruise missiles would be one of two types--the Rattler or the Dragon. The probable direction from which

*For explanatory purposes only. Different but similar scenarios will be used for testing purposes.

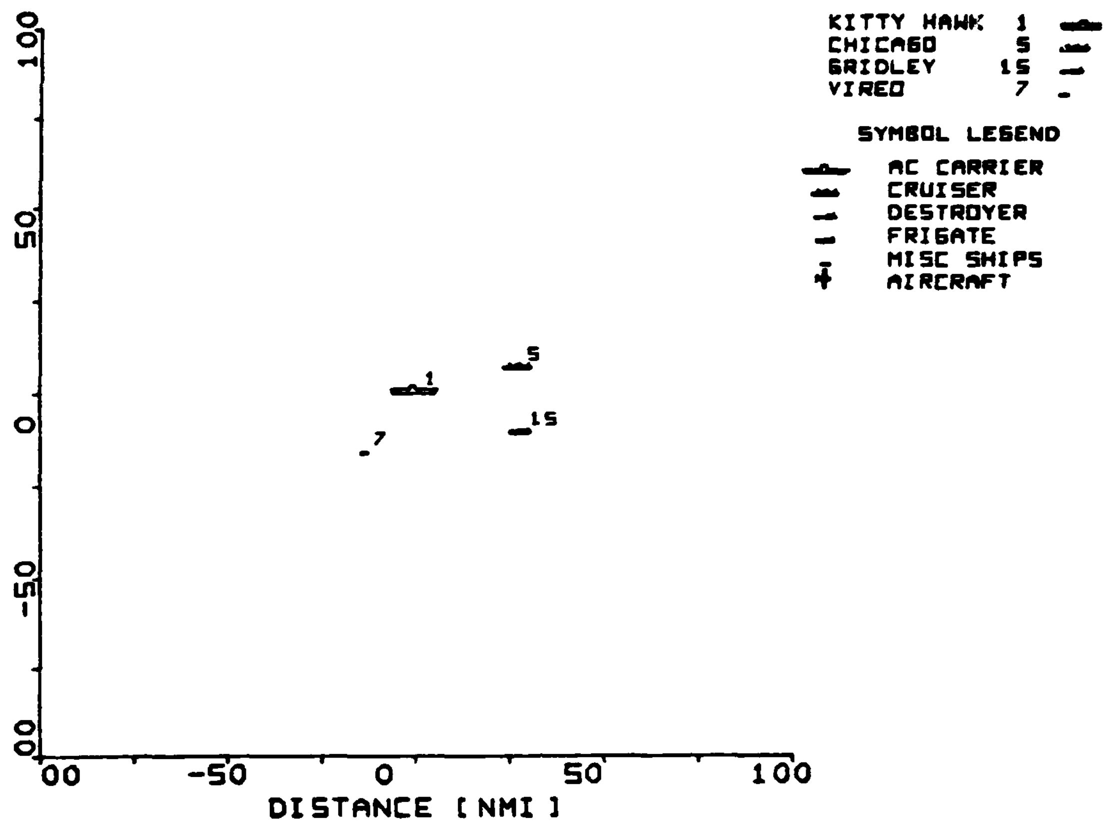


Figure 1. Task Force Disposition

---

the attack would come is not known, but intelligence estimates of operating altitudes, speeds, and radar cross sections of Rattler and Dragon missiles are available.

To defend against an attack, the task force commander would use his fighter aircraft, which are either "on alert" aboard the Kitty Hawk or "on patrol" in the vicinity of the task force. To detect and intercept attacking enemy cruise

missiles, the commander would rely on information provided by task force ship radars. The kinds of radars vary from ship to ship, as shown in Fig. 2.

1.4 THE EMCON PROBLEM

If air surveillance (i.e., radar coverage) were the only concern of the task force commander, he could maximize his probability of detecting and intercepting enemy missiles merely by turning on all of the radars on task force ships. However, to do so would result in providing the enemy with valuable information; different radar types emit different characteristic signals, and the enemy could use this information to identify and pinpoint the locations of the more valuable ships in the task force, as illustrated below (Developing an EMCON Plan). Given such knowledge, the enemy could plan his strike to attack the Kitty Hawk, which is the most important single vessel in the task force, and to essentially ignore the less valuable ships. Thus, turning on all task force radars in order to maximize surveillance coverage could result in greater damage to the task force than if some air surveillance coverage were sacrificed in order to deny ship identity information to the enemy.*

*In this scenario, Rattler and Dragon missiles are incapable of discriminating between more and less valuable ships; their targets are selected for them on the basis of information available to the enemy prior to missile launch. Further, aircraft visual and IR reconnaissance cannot be used by the enemy--as a means of identifying individual-ships--because of the fighter cover provided by Kitty Hawk aircraft.

Ship	SPS-10	SPS-30	SPS-43	SPS-48	SPS-52	SPS-37
Kitty Hawk	X	X	X		X	
Chicago	X	X	X	X	X	
Gridley	X		X	X		X
Vireo	X					

Figure 2. Radar Types Aboard Ships

There is therefore a fundamental trade-off between surveillance--the ability to detect an attacker--and information denial--denying the enemy information about the task force dispositions. The development of "good" radar utilization plans--that is, plans that balance surveillance coverage against information denial in order to afford the greatest degree of protection to the task force--is one aspect of the "emissions control (EMCON)" problem. The officer charged by the task force commander with developing EMCON plans is the Electronics Warfare (EW) officer. The EWAR decision aid described in this manual has been developed to assist the EW officer in preparing these plans. For test purposes, the test subjects are EW officers.

1.5 DEVELOPING AN EMCON PLAN

Consider now the structure of the EMCON plan in more detail and in the form it is to be viewed by the test subjects. For the EW officer, the construction of the plan simply means determining the "state" of each radar in the task force; i.e., which radars are to be turned on and which are to be turned off. The specification of the "state" of each task force radar constitutes an EMCON plan--although not necessarily a "good" one.

To construct an EMCON plan, the EW officer attempts to examine the problem from the viewpoint of an enemy contemplating an attack against the task force. For test purposes, the following simplifying assumptions have been made:

1. The enemy is aware of the presence of the task force.
2. The enemy knows which ships are in the task force and which radars are aboard which ships. In effect, he has access to the task force radar order of battle shown in Fig. 2 above.
3. From his own radars, the enemy knows the locations of the ships in the task force, but does not know which ships are at which locations.
4. By triangulation or other means, the enemy is able to associate radars that are turned on with the location from which the radars are emitting.

Figure 3 illustrates an idealized radar display available to the enemy commander. The radar blips (labeled A, B, C and D) in the display correspond to the location of the ships in the task force. The radar identifiers (SPS-10, etc.) correspond to the task force radars that are turned on (all radars, in this case).

By comparing the radar identifiers with what he knows about the ships and radar order of battle of the task force (Fig. 2), it is obvious to the enemy that blip A is the Kitty Hawk, blip B is the Chicago, blip C is the Gridley, and blip D is the Vireo. Since the aircraft carrier Kitty Hawk is clearly the most important single ship in the task force, the enemy commander might well decide to allocate all 10 of his cruise missiles to an attack on that ship. The probability of the Kitty Hawk being put out of action by a 10-missile attack is much higher than it would be if the enemy commander had to "guess" which of two, or three, or four radar blips was the Kitty Hawk, and had to apportion his missiles among two or more target ships in an attempt to damage the Kitty Hawk.

Consider next a case in which the EW officer has developed an EMCON plan which specifies that only SPS-10 and SPS-43 radars will be turned on. The idealized radar display then available to the enemy commander is illustrated in Fig. 4.

Now the enemy commander can identify with certainty only the Vireo, which he knows does not have an SPS-43 radar. Essentially, he is forced to allocate his missiles based upon the assumption that any one of blips A, B, or C could be the Kitty Hawk. Ignoring for the moment the question of task force radar surveillance coverage lost in turning off all radars other than the SPS-10 and SPS-43, it is obvious that denying information to the enemy by controlling radar emissions can be of great benefit to the higher value ships in the task force, and therefore to the accomplishment of whatever mission has been given the task force commander.

With all task force radars off, and with no other information available, the enemy commander would be forced to assume that each of the four blips had an equal probability (0.25) of being the Kitty Hawk. However, turning

B
SPS-10
SPS-30
SPS-43
SPS-48
SPS-52

A
SPS-10
SPS-30
SPS-43
SPS-52

C
SPS-10
SPS-43
SPS-48
SPS-37

D
SPS-10

Figure 3. Idealized Enemy Radar Display.
All Task Force Radars On

B
SPS-10
SPS-43

A
SPS-10
SPS-43

C
SPS-10
SPS-43

D
SPS-10

Figure 4. Idealized Enemy Radar Display.
Only SPS-10 and SPS-43 Task Force
Radars Turned On

off all radars is not satisfactory because it denies the task force commander any chance of detecting and intercepting attacking missiles. Further, through the application of information denial guidelines developed in the preparation of the EWAR aid, it is possible in some cases to turn on certain combinations of task force radars which would lead the enemy commander to conclude that there is less than a 0.25 probability that blip A is the Kitty Hawk. Such a highly deceptive EMCON plan is most desirable, from the viewpoint of the task force commander, since it would provide him with a degree of radar surveillance and also could result in the Kitty Hawk not being attacked at all. The application of information denial guidelines in developing deceptive EMCON plans is discussed in more detail in Sec. 2.0 below.

1.6 THE USE OF THE EWAR DECISION AID IN DEVELOPING EMCON PLANS

The EWAR decision aid assists the EW officer by:

- Performing the quantitative calculations necessary for a more precise evaluation of alternative EMCON plans.
- Providing graphic displays which highlight weaknesses in EMCON plans and which suggest modifications to improve these plans.
- Providing quantitative bases for evaluating the merits of alternative EMCON plans.

Section 2.0 below illustrates EWAR decision aid displays and shows how to use these displays in developing and evaluating EMCON plans.

- Section 2.1 discusses order of battle displays.
- Section 2.2 focuses upon displays which are most useful in evaluating radar surveillance coverage.
- Section 2.3 details and explains six information denial guidelines which are useful in developing EMCON plans, and shows those displays which are used to evaluate the information denial effectiveness of EMCON plans.
- Section 2.4 shows trade-off displays which provide insights into alternative EMCON plans in terms of combined surveillance-information denial effectiveness. These displays provide a basis for selecting the "best" of a number of competing plans.

Section 3.0 suggests a procedure for test subject use in developing and evaluating alternative EMCON plans, using EWAR displays.

Section 4.0 is a brief summary.

Section 5.0 lists and explains the computer commands to be used in generating EWAR decision aid displays.

2.0 USE OF THE EWAR DECISION AID IN DEVELOPING AND EVALUATING EMCON PLANS

A number of EWAR displays have been developed to assist the EW officer in preparing and evaluating EMCON plans. In this manual, only those EWAR displays relevant to the University of Pennsylvania effectiveness tests are included.

For test purposes, EWAR displays have been grouped into four categories: order-of-battle, surveillance, information denial, and trade-off. Each of these categories is addressed individually below, but the test subjects should understand that these category separations are solely for the purpose of explanation and illustration; and that the concurrent usage of displays from different categories is often useful, and sometimes essential, in evaluating EMCON plans.

The order-of-battle displays summarize the dispositions and capabilities of relevant task force systems, and show intelligence estimates of the characteristics and capabilities of enemy systems. The surveillance and information denial displays provide insights into these aspects of various EMCON plans, and implicitly offer hints for improving surveillance or information denial effectiveness. Trade-off displays weigh the combined effects of surveillance and information denial for a given EMCON plan, and provide bases for decisions about the relative effectiveness of alternative plans.

2.1 ORDER-OF-BATTLE DISPLAYS

Certain EWAR "order-of-battle" displays provide a logical starting point for the development or evaluation of an EMCON plan. These are:

2.1.1 Task Force Disposition (See Fig. 1 under "The Scenario"): This display shows the numbers, kinds, names, and locations of task force ships. It is centered upon the highest value ship in the task force--in this case, the aircraft carrier Kitty Hawk.

2.1.2 <u>Task Force Search Radar Order of Battle</u> (Fig. 5): This display shows which kinds of search radars are aboard which task force ships, and also indicates which radars are operating under the current EMCON plan. In the computerized display, a ⊠ box (green in color display) matching a radar with a ship shows that radar type to be aboard that ship and operating under the current EMCON plan. A ▧ box (red in color display) shows that radar type to be aboard that ship but <u>not</u> operating; and a black box (blank in Fig. 5) shows that radar type is not aboard that ship. For example: There is an SPS-43 radar aboard the Kitty Hawk but it is not operating; there are SPS-43s aboard both the Chicago and Gridley, and both these radars are operating; and there is no SPS-43 aboard the Vireo.

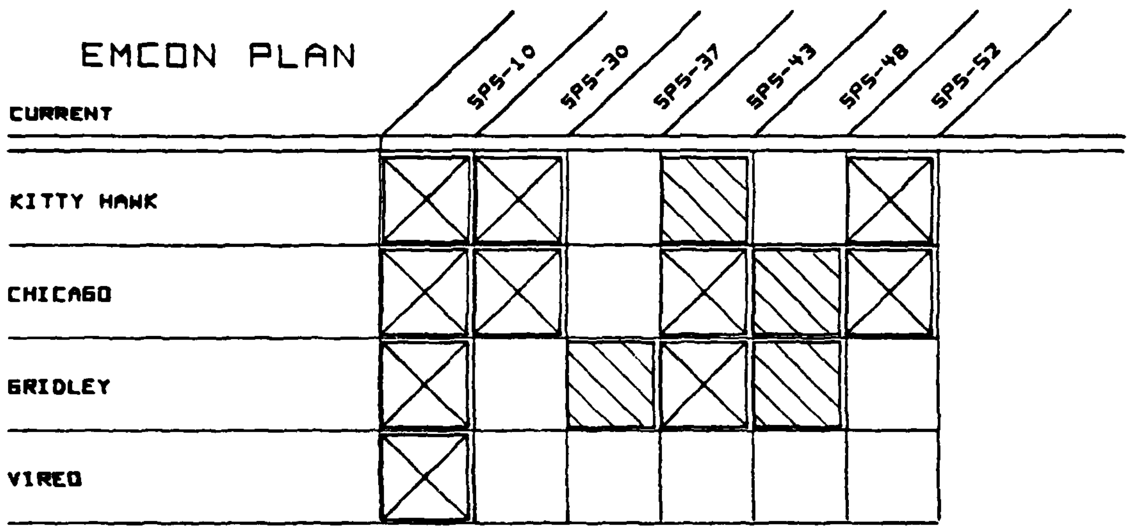


Figure 5. Search Radar Order of Battle

2.1.3 Ship Names, Identification Numbers, and "Values" (Fig. 6): This display lists all the ships in the task force as well as a "value" for each ship as estimated by the task force commander in planning this particular mission. In this case, the aircraft carrier Kitty Hawk is more important to mission accomplishment than are the other three ships combined. These assigned values are used to measure the expected effects of enemy attacks when different EMCON plans are employed; the total assigned value for the task force remaining after each simulated attack is one "measure of merit" for a given EMCON plan.

INDEX	SHIP	VALUE
1	Kitty Hawk	940
5	Chicago	203
7	Vireo	4
15	Gridley	91

Figure 6. Task Force Ship Names, Identification Numbers, and Values.

2.1.4 Threat Characteristics (Fig. 7): This display shows intelligence estimates of the pertinent characteristics of the enemy threat to the task force. The Dragon cruise missile normally operates at an altitude of about 655 ft and a speed of 675 knots (nautical miles per hour). It has a radar cross section of about one-tenth of a square meter. These values are used in the EWAR decision aid to calculate probabilities of detection, tracking, interception, and destruction of threat vehicles. There is a similar display (not shown) for the other threat system--the Rattler.

THREAT ID	= DRAGON
ALTITUDE (FT)	= 655.7
RADAR CROSS SECTION (SQM)	= 0.1
VELOCITY (KNOTS)	= 675.0

Figure 7. Threat Characteristics

2.2 SURVEILLANCE ANALYSIS DISPLAYS

Several surveillance diagnostic displays are available in the EWAR decision aid to provide the EW officer insights into the effects of various EMCON plans on task force surveillance/air defense capability:

2.2.1 Maximum Detection Ranges for Search Radars (Fig. 8)

This display shows the maximum detection range for each of the task force radars against each threat. All the radars listed are air-search radars except the SPS-10 (sea-search), which--as indicated in Fig. 8--has only a limited air-search capability.

2.2.2 Maximum Detection Range Map (Fig. 9)

This display combines the detection range data for the Dragon threat (Fig. 7) with task force geographic disposition (Fig. 1) and the current EMCON plan (Fig. 5). It also shows sea state, weather information, and degree of enemy radar jamming (clear weather and no jamming, in this case). A display such as this for each EMCON plan being examined provides the EW officer a visual representation of radar surveillance coverage, and will immediately show any obvious gaps in such coverage.

2.2.3 Probability-of-Detection Contours (Fig. 10)

This display shows the EW officer--for a given EMCON plan--the probability that a threat system directed toward the Kitty Hawk will be detected by operating task force radars by the time it reaches a given point. For example, there is a 90% (0.9) probability that a Dragon missile would be detected by the time it reached any point on the inner contour; a 50% probability of detection by the time it reached any point on the intermediate contour; and a 30% probability of detection by the time it reached any point on the outer contour. This display provides the

	RATTLER	DRAGON
SPS-43	64.	54.
SPS-48	63.	53.
SPS-10	7.	6.
SPS-30	18.	15.
SPS-52	63.	53.
SPS-37	64.	54.

Figure 8. Task Force Search Radar Maximum Detection Ranges (Maximum Detection Range in nmi)

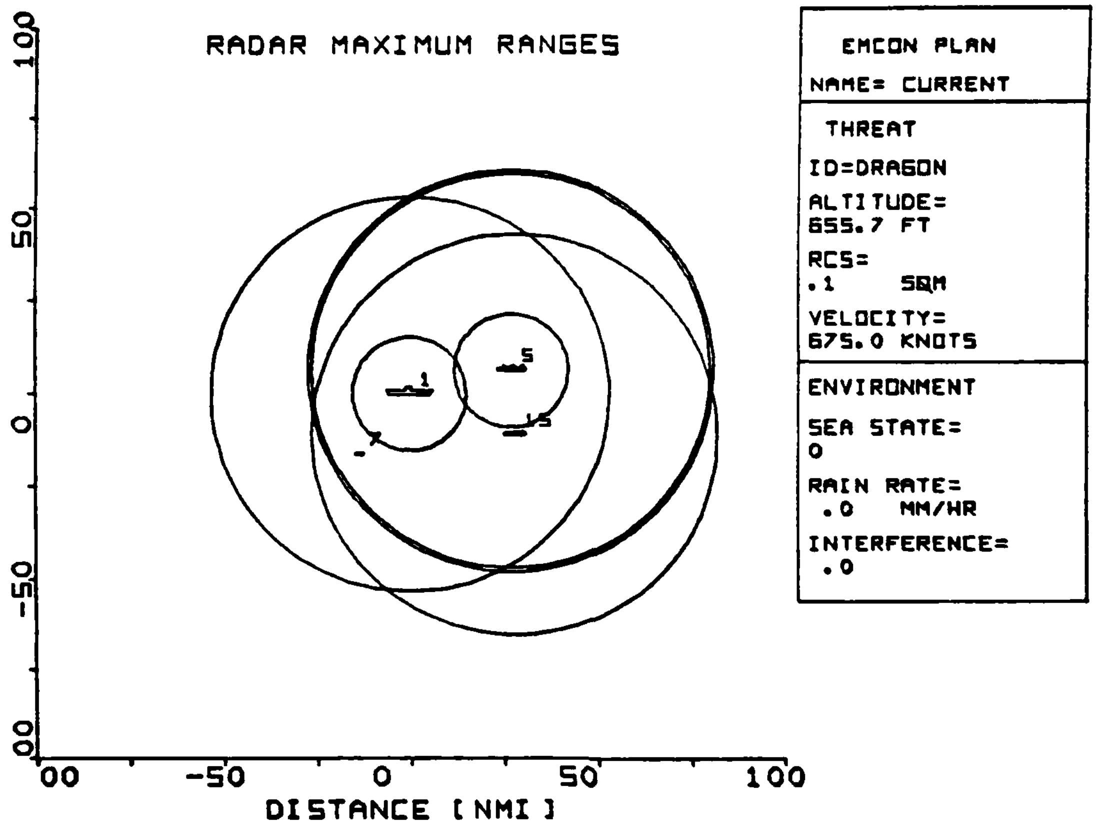


Figure 9. Search Radar Maximum Detection Range Map

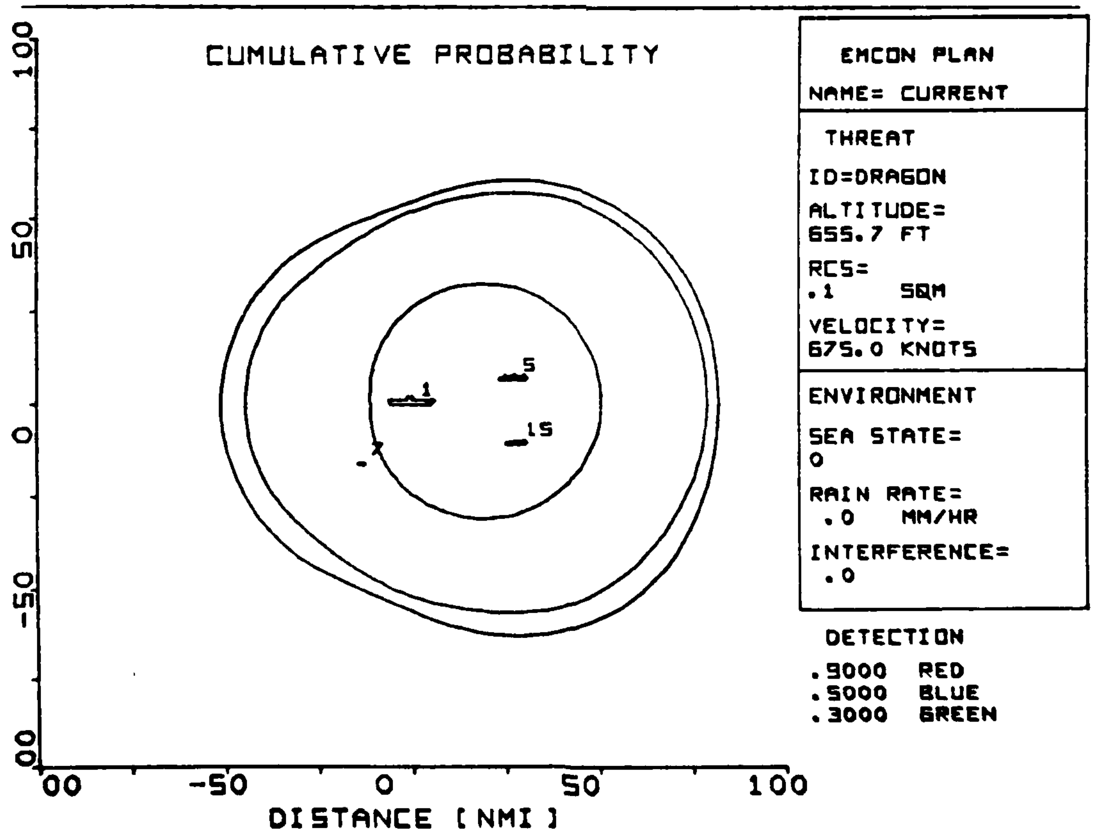


Figure 10. Probability-of-Detection Contours

EW officer useful insights into the question of the adequacy of surveillance coverage for the EMCON plan being evaluated.

2.2.4 Surveillance Score: Interception Probabilities (Fig. 11)

For the purpose of comparing surveillance effectiveness of alternative EMCON plans, the EW officer needs a numerical index that reflects this effectiveness. Such an index has been developed for the EWAR decision aid on the basis of estimated task force radar and fighter aircraft effectiveness against the postulated threat. Theoretical index bounds are 0.0 for an ALL RADARS OFF condition and 1.0 for a perfect air defense capability. Since, in this example, the radars and fighter aircraft of the task force are not capable of providing such a "perfect" defense against the Rattler/Dragon threats, the effective upper bound for the index, achieved with all radars operating, is 0.70 against the Rattler; 0.47 against the Dragon; and 0.58 (average index) for the two threat systems. The rather small differences in the "Current Plan" and "ALL ON" indicate to the EW officer that turning on additional radars (i.e., those turned off in the current EMCON plan) would not result in much additional protection for the task force.

2.2.5 Surveillance Strike Results (Fig. 12)

This display shows projected results for an enemy strike (with the Dragon missile, in this case), considering the degree of surveillance/air defense protection afforded by the current EMCON plan. However, the results in this display assume that the enemy has perfect intelligence about task force dispositions; that

EMCON PLAN = CURRENT

SURVEILLANCE SCORE----INTERCEPTION PROBABILITIES

THREAT NAME	INTERCEPTION PROBABILITY CURRENT PLAN	ALL ON	WEIGHT
RATTLER	.65	.70	.50
DRAGON	.40	.47	.50
	.53	.58	

Figure 11. Surveillance Score: Interception Probabilities

OPTIMAL STRIKE
ATTACKER KNOWS SHIP IDENTITY
FRACTIONAL VALUE REMAINING = .439
EMCON PLAN = CURRENT

THREAT	SHIP	ALLO-CATION	PEN. PROB.	# HITS	FRACTION REMAIN	SHIP INIT	VALUE REMAIN
DRAGON	KITTY HAWK	10	0.609	5.5	0.26	939	245
	CHICAGO	0	--	--	--	203	203
	VIREO	0	--	--	--	4	4
	GRIDLEY	0	--	--	--	91	91
		10	--	5.5	--	1,237	543

Figure 12. Surveillance Strike Results

is, he knows which blip is which ship, he knows the value of each ship, and he knows the degree of protection afforded each ship. With such knowledge, he would reasonably direct all 10 Dragon missiles at the Kitty Hawk. Using expected value calculations, 6+ Dragons would penetrate the task force air defense system; 5+ of these missiles would hit the Kitty Hawk, resulting in the destruction of about 74% of the value of that ship (corresponding to the destruction of about 56% of total task force value). The "fractional (task force) value remaining" of 0.439 provides a basis for the EW officer to evaluate the "information denial" value of the current EMCON plan, as discussed in more detail under the section on information denial analysis below.

In summary, the principal EWAR decision aid "surveillance analysis" displays available to the EW officer are:

- A listing of task force radar detection ranges for each postulated threat (Fig. 8)
- A map relating this detection range data to the geographic disposition of the fleet and to the current EMCON plan (Fig. 9)
- A map showing probability-of-detection contours (for the EMCON plan being evaluated) for each postulated threat (Fig. 10)

- A "surveillance score" (numerical index) for the EMCON plan being evaluated (Fig. 11)
- A summary of the expected results of an enemy attack, considering the degree of surveillance/air defense protection afforded the task force by the current EMCON plan, but assuming that the enemy has "perfect intelligence" about task force dispositions (Fig. 12)

2.3 INFORMATION DENIAL ANALYSIS

The objective of an EMCON plan in this scenario is to deny useful information to the enemy to the extent possible without degrading surveillance/air defense capabilities to an unacceptable level. This section addresses the "information denial" aspect of the problem. It explains six "information denial" guidelines developed for the EWAR decision aid and shows how the application of these guidelines in EMCON plan development can result in denying useful information to the enemy, thereby complicating his targeting problem and effectively resulting in a higher level of protection for the task force. It also illustrates the EWAR decision aid displays available to the EW officer for evaluating the information denial utility of an EMCON plan.

2.3.1 Six Guidelines for Limiting Information Disclosed by an EMCON Plan

A detailed investigation of the EMCON problem led to the development of six "information denial" guidelines (Fig. 13) for the use of the EW officer in conjunction with the EWAR decision aid.

---

1. Avoid turning on a unique radar (i.e., a radar present on only one ship in a task force) or a unique combination of radars.
2. Turn on all radars common to all ships.
3. Look for radar groups (i.e., radars which always appear together); turn such radars on or off as a group.
4. Turn off all radars in the task force that are not aboard any ship to be "hidden."
5. Turn off all radars aboard any ship to be hidden, except for those radars which are common to all ships in the task force.
6. Turn on a radar or radars aboard an intermediate value ship in those situations where such an action would result in a low value ship being identifiable only as itself or as a high value ship.

Figure 13. Information Denial Guidelines

2.3.2 The Application of the Six Information Denial Guidelines

These guidelines are useful both in evaluating an existing EMCON plan and in developing alternative plans. By testing an existing plan for compliance with the guidelines, the EW officer can readily develop hypotheses about improving the information denial aspects of the plan. For example, testing the current EMCON plan (Fig. 5, reproduced below as Fig. 14) for compliance with the guidelines results in the following preliminary conclusions:

- The plan complies with guideline 1: Avoid turning on a unique radar or a unique combination of radars. The only unique radar is the SPS-37 aboard the Gridley, and this radar is turned off. The only unique radar combinations in the task force are those aboard the Chicago--the SPS-48/SPS-30 and the SPS-48/SPS-52 combinations. Since the SPS-48 radar aboard the Chicago is turned off, neither of these unique combinations appears on the enemy's radar display.
- The plan complies with guideline 2: Turn on all radars common to all ships. The SPS-10 is the only radar common to all ships, and all SPS-10s are turned on.
- The plan complies with guideline 3: Look for radar groups; turn such radars on or off as a group. The only radar group in this task force is the SPS-30/SPS-52 pair aboard both the Kitty Hawk and the Chicago. Both radar pairs are turned on. There would still be compliance with the guideline if one pair were turned on and one pair turned off; the guideline would only be violated if one radar were on and one were off in a given pair.

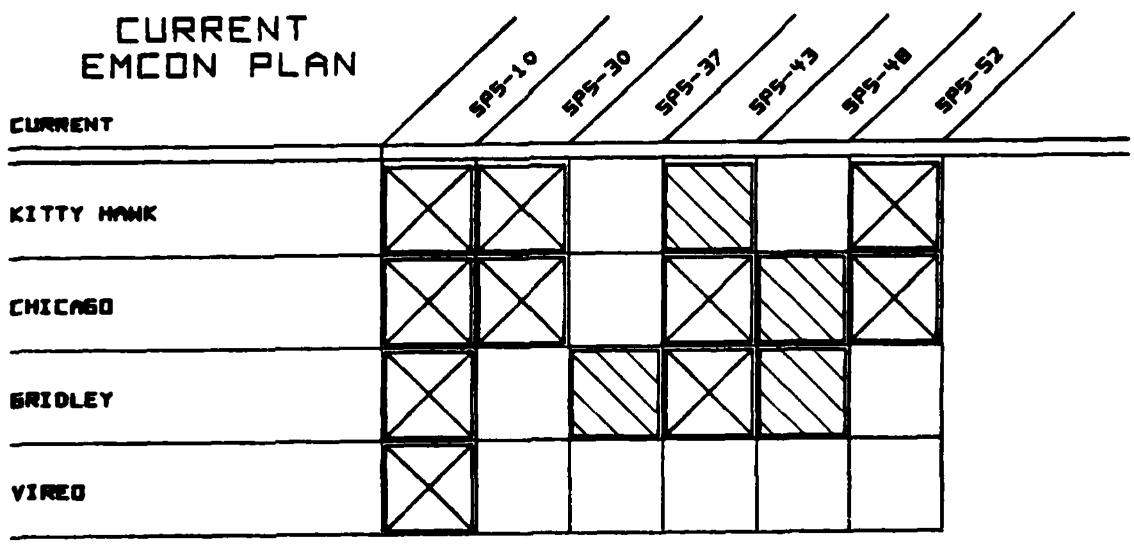


Figure 14. Search Radar Order of Battle

- The plan complies with guideline 4: Turn off all radars in the task force that are not aboard any ship to be "hidden." In this task force, the Kitty Hawk is the ship to be hidden. The only task force radar types which are not aboard the Kitty Hawk are the SPS-48s and the SPS-37, and all of these radars are turned off.

- The plan violates guideline 5: Turn off all radars aboard any ship to be hidden, except for those radars which are common to all ships in the task force. The SPS-30 and SPS-52 radars aboard the Kitty Hawk are turned on; these radars are not common to all ships in the task force. The EW officer notes this non-compliance and decides to examine an EMCON plan (at a later time) with these Kitty Hawk radars off.

- The plan does not comply with guideline 6: Turn on a radar or radars aboard an intermediate value ship in those situations where such an action would result in a low value ship being identified only as itself or as a high value ship. The application of this guideline is rather complicated. The essence of the guideline is this: If the low value ship can only be identified as itself or as the high value ship, then there is a good probability that it will be incorrectly identified as the high value ship. Such an outcome is desirable, from the EW officer's standpoint. For example, in this scenario it implies that some of the missiles threatening the Kitty Hawk would be "wasted" on the Vireo. If the Vireo could also plausibly be mistaken for an intermediate value ship such as the Gridley, then there would be a lesser probability that the Vireo would be mistakenly identified as the Kitty Hawk, and fewer missiles would be "drawn away" from the Kitty Hawk by the Vireo.

  Guideline 6 has not been applied in the current EMCON plan: The SPS-30 and SPS-52 emissions from the Kitty Hawk blip show the enemy that this blip could not be the Vireo, since the Vireo has neither of these radar types. The guideline would be effectively followed if these two radars aboard the Kitty Hawk were turned off so that the Vireo could be assigned to the Kitty Hawk blip. In this case, the act of turning on the SPS-43 radar on the Gridley (intermediate value ship), which would prevent the Gridley blip from mistakenly being identified as the Vireo, would permit the Vireo to be assignable to only its own blip or to the Kitty Hawk. The EW officer notes this possible application of guideline 6 for further study.

2.3.3 Information-Denial Analysis: EWAR Displays

A number of EWAR decision aid displays have been developed to assist the EW officer in evaluating the amount of useful information denied to an enemy by a given EMCON plan. The displays developed each assumes that the enemy commander is

a rational individual who will make the best possible use of information provided him by task force radar emissions. The EWAR displays below show:

- Those task force ships which could plausibly be assigned to a given blip (Ship-to-Blip Assignments)
- Those blips which could plausibly be assumed to be a given ship (Blip-to-Ship Assignments)
- The probability that a given blip is a given ship
- The probability that a given task force ship will be correctly identified
- A comparison of "actual" ship value to "perceived" ship value (i.e., value derived from radar emission information available to the enemy)
- Information Denial scores

Figure 15 illustrates an idealized radar display available to the enemy commander with the current task force EMCON plan implemented. The radar blips--labeled A (Kitty Hawk), B (Chicago), C (Gridley), and D (Vireo)--correspond to the location of the ships in the task force. The radar designations (SPS-43, etc.) correspond to the radar emissions coming from each of the blips.

B
SPS-43
SPS-10
SPS-30
SPS-52

A
SPS-10
SPS-30
SPS-52

C
SPS-43
SPS-10

D
SPS-10

Figure 15. Idealized Enemy Radar Display -- Current EMCON Plan

Using probability theory, the EW officer--or the enemy commander's staff--can use this display information to calculate the probability that a given blip is a certain ship, that a given ship is a certain blip, etc., etc. However, such calculations can become tedious and unacceptably time-consuming, especially for larger task forces. The EWAR decision aid makes all these calculations for the EW officer, and displays the results in the following manner:

- Ship-to-Blip Assignments (Fig. 16): This display lists those ships which could logically be assigned to a given blip. In this example, the A (Kitty Hawk) blip is being examined. The display shows that the enemy cannot be certain whether this blip is being emitted by the Kitty Hawk or the Chicago; however, he knows it cannot be either the Gridley or the Vireo, since neither of those ships has SPS-30 or SPS-52 radars. Had guideline 5 been followed--"Turn off all radars aboard any ship to be hidden, except for those radars which are common to all ships in the task force"--all task force ships would have been listed in this display of the Kitty Hawk blip. A ship-to-blip assignment display for any other task force ship can also be examined.
- Blip-to-Ship Assignments (Fig. 17): This display lists those blips that an attacker may think is a given ship (the Kitty Hawk, in this example), based on radar emission information. Since each of the four blips shows a pattern of emissions which could come from the Kitty Hawk, the conclusion that any of the blips could be the Kitty Hawk is reasonable; when any task force blip could plausibly be assumed to be emitted by the ship to be "hidden," the EW officer knows there is compliance with guideline 4--"Turn off all radars in the task force that are not aboard any ship to be hidden."

  This display can also be used to determine compliance with guideline 6--"Turn on a radar or radars aboard an intermediate value ship in those situations where such an action would result in a low value ship being identified only as itself or as a high value ship." In this scenario, if the blip-to-ship assignment display for the Vireo listed only that low value ship and the Kitty Hawk, compliance with guideline 6 would be demonstrated.

EMCON PLAN = CURRENT

SHIPS WHICH COULD BE ASSIGNED TO THE BLIP EMITTED BY KITTY HAWK

SHIP	CLASS	TYPE	VALUE
KITTY HAWK	KITTY HAWK	CARRIER	940
CHICAGO	ALBANY	CRUISER	204

Figure 16. Ship-to-Blip Assignments

EMCON PLAN = CURRENT
BLIPS THAT AN ATTACKER MAY THINK IS KITTY HAWK

BLIP	CLASS	TYPE	VALUE
KITTY HAWK	KITTY HAWK	CARRIER	939.5
CHICAGO	ALBANY	CRUISER	203.5
VIREO	BLUEBIRD	MINESWEEPER	3.7
GRIDLEY	LEAHY	FRIGATE	90.7

Figure 17. Blip-to-Ship Assignments

- Probability That a Given Blip is a Given Ship (Fig. 18): This display shows the probability that a rational enemy would assign to the likelihood of, e.g., the Kitty Hawk blip corresponding to each of the task force ships. In this case, under the current EMCON plan, the enemy would reasonably conclude that there is a 50% probability that the A blip corresponds to the Kitty Hawk and an identical probability that it corresponds to the Chicago. The same probabilities exist for the B blip; from the enemy's standpoint, there is a 50% probability that it corresponds to the Kitty Hawk and a similar probability that it corresponds to the Chicago. On the other hand, the display shows that the enemy can unambiguously identify both the Gridley and the Vireo, by elimination. The Vireo has only one radar--the SPS-10--so blips A, B, and C are eliminated, and blip D is the Vireo. The Gridley has neither an SPS-30 nor an SPS-52 radar, so blip C must be the Gridley.

  One can readily see that, if all the task force radars were turned off, this display would show a 25% probability (0.25) that each of the blips corresponded to each of the four task force ships.

EMCON PLAN = CURRENT

BLIP	IDENTIFIED AS	WITH PROBABILITY
KITTY HAWK	KITTY HAWK	.50
	CHICAGO	.50
CHICAGO	KITTY HAWK	.50
	CHICAGO	.50
GRIDLEY	GRIDLEY	1.00
VIREO	VIREO	1.00

Figure 18. Probability That a Given Blip is a Given Ship

- Probability That a Given Ship Will Be Correctly Identified (Fig. 19): This display combines and summarizes the probabilities in the three previous displays. It shows the probability that the enemy will be able to correctly identify each of the task force ships solely on the basis of their radar emissions. In this rather simplistic example, he can correctly identify both the Gridley and the Vireo with certainty, and has a 50% chance of correctly identifying both the Kitty Hawk and the Chicago. In actual practice it is unlikely that he would effectively flip a coin and devote his entire attack to one or the other of blips A and B; rather, he would split his attack between these two blips. Thus, the current EMCON plan does result in a certain degree of deception compared to an ALL RADARS ON Plan where each ship could be unambiguously identified.

Figures 18 and 19 show the EW officer that he can safely turn on the SPS-37 and SPS-48 radars aboard the Gridley. These radars were originally turned off in compliance with information denial guidelines 1 (Avoid turning on a unique radar--the SPS-37) and 4 (Turn off all radars that are not aboard a ship to be hidden--both the SPS-37 and the SPS-48). The purpose of these guidelines, in this case, was to increase the probability that a lower value ship--the Gridley--would be mistakenly identified as the Kitty Hawk. However, since the Gridley can be unambiguously identified anyway under the current EMCON plan, turning on these radars provides the enemy with no information he does not already have, and may result in improved task force surveillance coverage.

- Comparison: "Actual" Ship Value and "Perceived" Blip Value (Fig. 20): This display compares the value of each blip as perceived by the enemy with the actual value of the ship emitting that blip. Bar lengths are proportional to value. As indicated in the previous display, a rational enemy commander who did not have enough weapons to ensure a high probability of destroying each task force ship would split his weapons between the Kitty Hawk and the Chicago, based upon these perceived values. Thus, again, the current EMCON plan is

---

EMCON PLAN = CURRENT

SHIP NAME	PROBABILITY OF CORRECT ID			
	SIDE	TYPE	CLASS	SHIP
KITTY HAWK	1.00	.50	.50	.50
CHICAGO	1.00	.50	.50	.50
GRIDLEY	1.00	1.00	1.00	1.00
VIREO	1.00	1.00	1.00	1.00

Figure 19. Probability of Correct Ship Identification

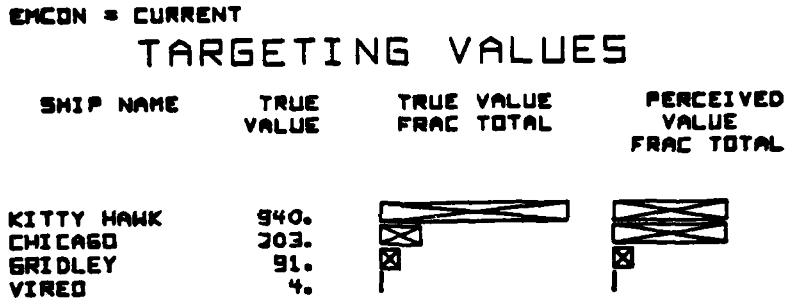


Figure 20. Actual Ship Value and Perceived Blip Value Compared

somewhat deceptive because it results in some weapons being drawn away from the Kitty Hawk. A more deceptive plan would result in larger perceived values for the Gridley and Vireo, and a smaller value for the Kitty Hawk; and a highly deceptive plan would essentially reverse the perceived value bars of the Kitty Hawk and the Vireo. However, such a degree of deception is not always attainable; its achievement is constrained both by the actual radar order of battle of the task force and by surveillance requirements.

- Information Denial Scores (Fig. 21): As was the case with the "surveillance score" (Fig. 11), the EW officer needs a quantitative index which will give him insights into the amount of information a particular EMCON plan denies the enemy. Such an index has been developed for the EWAR decision aid. An information denial score of 0.00 indicates that the EMCON plan is completely ineffective; it denies no information, and corresponds in this example to the ALL RADARS ON case in which the enemy can readily identify each

EMCON PLAN = CURRENT

INFORMATION DENIED	SCORE
ALL EMITTERS OFF	.36
CURRENT STATUS	.16
ALL EMITTERS ON	.00

Figure 21. Information Denial Scores

blip on his radar screen. (Normally, the ALL ON plan does not give away this much information.) A score of 1.00 would mean that the attacker has no information at all, and in fact is not even aware that the task force exists. For this scenario, the ALL RADARS off score--which depends on task force composition--is 0.36. An information denial score greater than 0.36 would be characteristic of the kind of truly deceptive EMCON plan that sometimes results from the application of information denial guideline 6. The current EMCON plan, according to the display, has a score of 0.16, which is well below the ALL RADARS OFF score, and which suggests that this EMCON plan gives away too much information. The noncompliance of this plan with information denial guidelines 5 and 6 had already indicated such a possibility to the EW officer, and the information denial score suggests that a more deceptive EMCON plan could be developed.

2.4 TRADE-OFF ANALYSIS

The previous sections on surveillance analysis and information denial analysis showed the various displays in the EWAR decision aid which quantify these aspects of the EMCON problem. Three EWAR "trade-off" displays have been developed to enable the EW officer to relate the results of the surveillance and information denial analyses to one another, and to provide a basis for evaluating the overall effectiveness of an EMCON plan.

2.4.1 Trade-off Map Summary Display (Fig. 22)

This display combines the results from the detection probability contour data from Fig. 10 with the "actual" and "perceived" value data from Fig. 20. The ship symbol sizes are proportional to actual values, and the line beneath each ship is proportional to perceived values. This display is intended to give the planner an overall feeling about the quality of an EMCON plan: It suggests both how an enemy will allocate his weapons and how easily these weapons can reach the target. In this case, it reminds the EW officer that the surveillance/air defense coverage is reasonably good, and that an enemy is likely to direct half his weapons to Kitty Hawk (1) and half to Chicago (5).

2.4.2 Combined Surveillance and Information Scores (Fig. 23)

This graph compares the surveillance and information scores for each EMCON plan being evaluated (in this case, only the current EMCON plan), as well as the scores for the ALL RADARS ON and ALL RADARS OFF plans. Surveillance scores are plotted on the left vertical axis and information denial scores on the right vertical axis. As indicated previously, the ALL RADARS ON case provides the best surveillance coverage, but not much more than does the current EMCON plan,

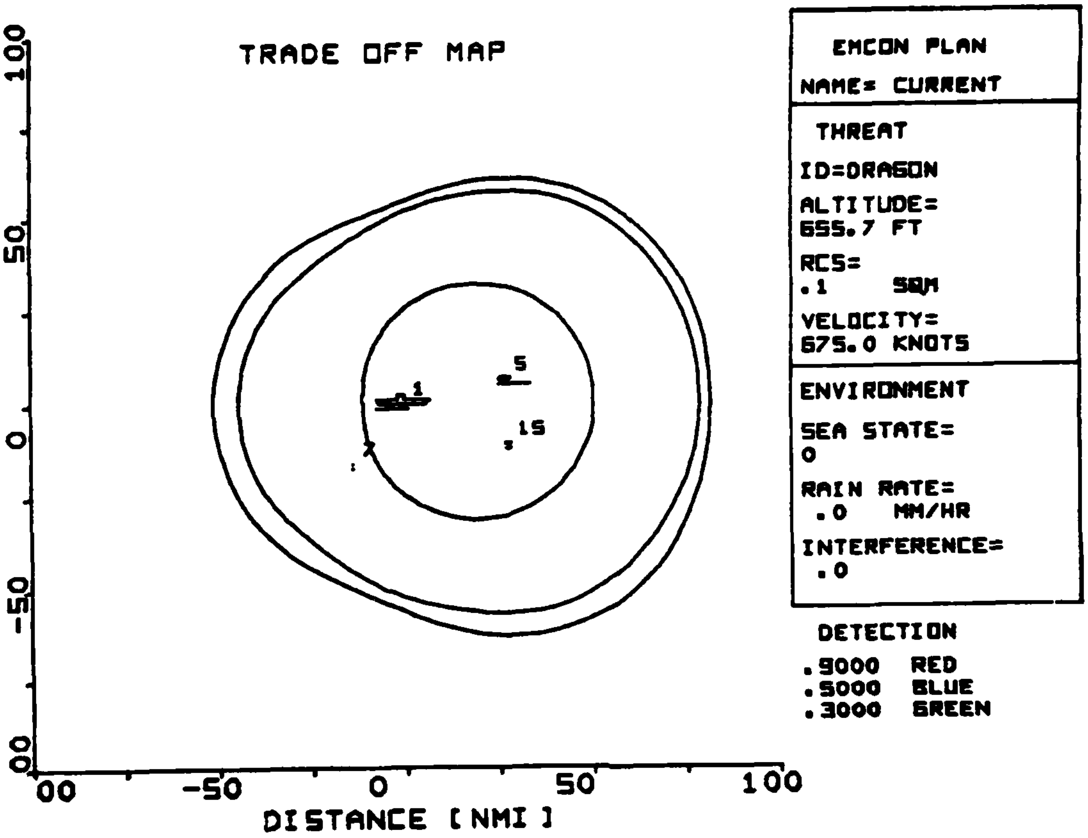
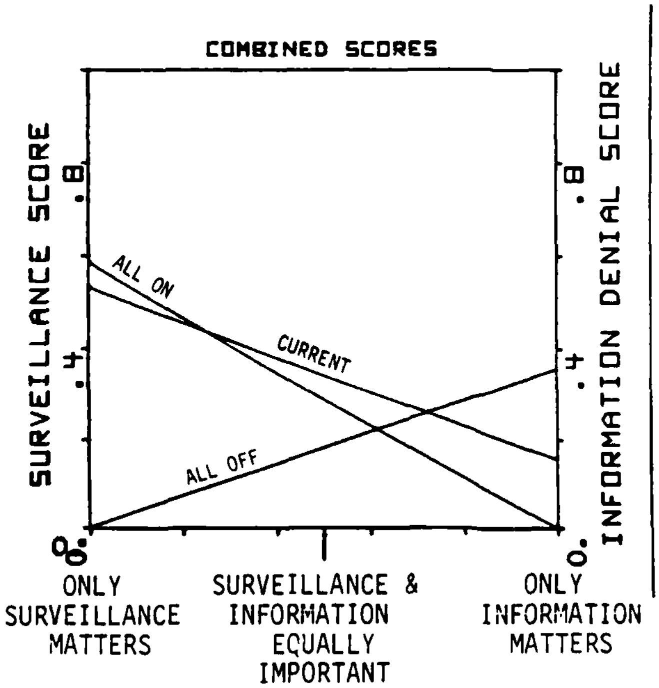


Figure 22. Trade-Off Map Summary



EMCON ALTERNATIVES	PURE SCORES SV.	EW
CURRENT	.53	.16
ALL ON	.59	.00
ALL OFF	.0	.36

Figure 23. Summary of Surveillance and Information Denial Score

while the ALL RADARS OFF case obviously provides no surveillance coverage at all. On the other hand, the ALL RADARS ON case denies no information to the enemy, while the information denial "values" of the ALL RADARS OFF and the current EMCON plan cases are 0.36 and 0.16, respectively.

The horizontal scale shows the EW officer where to enter the graph if he can quantify the relative importance to him of satisfying surveillance requirements and denying information to the enemy. For example, if he felt these two aspects were equally important, he would enter the graph at the midpoint on the horizontal line, read directly upward, and note that the current EMCON plan gives better results than either the ALL ON or ALL OFF case. While this graph provides the EW officer an indication of the trade-offs among various EMCON plans, and can show him when a given plan clearly dominates another plan, it does not provide him any insights into the problem of establishing "relative values" for weighting the surveillance and information denial scores.

2.4.3 Task Force Value Surviving Based on Perceived Values

Since the essence of the EMCON plan is the protection of the task force, and since a value has been assigned to each ship in the task force in accordance with its contribution to the accomplishment of the task force mission, one measure of merit for an EMCON plan is the amount of the total task force value it protects; that is, the amount of task force value surviving after an enemy strike which is launched against the surveillance/air defense coverage provided by an EMCON plan, and which is based upon the information provided an enemy by task force emissions resulting from the implementation of that EMCON plan.

Figure 24 shows the projected results of such a strike, based upon the assumption that the enemy is rational and will attempt to maximize the amount of task force "value" he destroys. The projected result--0.462 of task value destroyed (i.e., "fractional value remaining = 0.538") is the best the enemy could do, based upon the surveillance coverage provided, task force radar emissions, the capabilities of (in this example) the Dragon missile, the effectiveness of the task force defenses against the Dragon missile, and the perceived blip values that a rational enemy would use in structuring his attack. A similar display can be developed for the Rattler missile, the less threatening of the two systems which might be used against the task force.

OPTIMAL STRIKE
ATTACKER GUESSES SHIP IDENTITY
PLEASE ENTER NEW EMCON PLAN NAME CURRENT

FRACTIONAL VALUE REMAINING = .538
EMCON PLAN = CURRENT

THREAT	SHIP	ALLO-CATION	PEN PROB.	# HITS	FRACTION REMAIN	SHIP INIT	VALUE REMAIN
DRAGON	KITTY HAWK	5	0.609	2.7	0.51	939.5	479.8
	CHICAGO	5	0.531	1.7	0.45	203.5	91.8
	VIREO	0	--	--	--	3.7	3.7
	GRIDLEY	0	--	--	--	90.7	90.7
		10	--	4.4		1,237.4	666.0

Figure 24. Task Force Value Surviving

In addition to providing the EW officer a "measure of merit" for each EMCON plan considered--which he can use to determine how "good" an EMCON plan is, based upon information available to him--this display provides the basis for measuring the information denial value of a given EMCON plan. In Sec. 2.1 above, the final surveillance display--"Surveillance Strike Results" (Fig. 12)--showed a fractional task force value remaining of .439 in a case identical to that shown in Fig. 24, <u>except</u> that the results in Fig. 12 assume the enemy has perfect information about task force dispositions. Thus, the difference in task force value remaining (0.538 - 0.439 = 0.99) is a measure of the value of the information denied to the enemy by the current EMCON plan.

This final trade-off display--Task Force Value Surviving--adequately summarizes for the test subject one measure of the effectiveness of the EMCON plans he is evaluating. However, it is of no value to him in providing hints for improving a given EMCON plan. Insights that provide clues to the development of better EMCON plans come from the surveillance and information denial displays described previously, and from the application of the six information denial principles.

3.0 DEVELOPING ALTERNATIVE EMCON PLANS

A suggested procedure for developing EMCON plans is outlined in Fig. 25 below.

---

1. *Obtain all relevant order-of-battle information* (EWAR decision aid displays shown in Figs. 1, 5, 6, and 7).

2. *Construct a baseline plan that follows the six information denial guidelines* (Fig. 13). Generate a "Search Radar Order of Battle" display (Fig. 14) for this plan.

3. *Examine the information denial aspects of the plan.*
   - Check for compliance with information guidelines (Search Radar Order of Battle display and the displays illustrated in Figs. 16 through 20).
   - Generate information denial "score" (See Fig. 21).

4. *Examine surveillance coverage afforded by the plan.*
   - Generate surveillance coverage displays (illustrated in Figs. 9 and 10).
   - Generate surveillance "score" (See Fig. 11) and "Surveillance Strike" (worst case) displays (Fig. 12).

5. *Examine information denial-surveillance coverage trade-offs* (See Figs. 22 through 24).

6. *Formulate hypotheses for improving information denial or surveillance coverage aspects of the plan.*

7. *Test hypotheses by developing alternative EMCON plans.* Evaluate these plans as suggested in steps 3 through 5 above.

8. *Select the "best" EMCON plan or plans*, based upon whatever guidance has been given by the task force commander.

Figure 25. Suggested Procedure: EMCON Plan Generation

Continuing the example from Section 2.0: The EW officer prepares a new EMCON plan ("INFO") as suggested in step 2, which results in the radar states shown in Fig. 26.

Note the changes made to bring EMCON plan INFO into agreement with the six information denial guidelines. The previous plan violated guideline 5--"Turn off all radars aboard any ship to be hidden, except for those radars which are common to all ships in the task force"--because the SPS-30 and SPS-52 radars aboard the Kitty Hawk were turned on. In plan INFO these two radars are turned off so that there is compliance with guideline 5. Turning off these two radars also permits compliance with guideline 6--"Turn on a radar or radars aboard an <u>intermediate</u> value ship in those situations where such an action would result in a <u>low</u> value ship being identified only as itself or as a <u>high</u> value ship." With the SPS-43 aboard the Gridley turned on, radar emissions data alone would not permit the enemy to differentiate between the Kitty Hawk and the lowest value ship--Vireo.

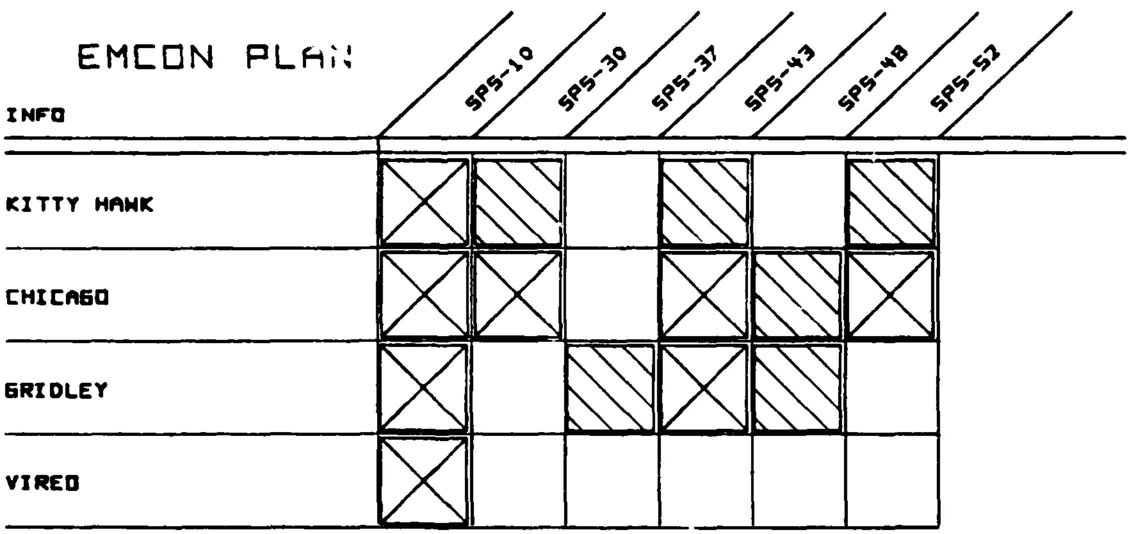


Figure 26. Search Radar Order of Battle

The EW officer believes that EMCON plan INFO complies with the information denial guidelines, so he examines a number of displays to determine the effect of this compliance.

3.1 INFORMATION DENIAL ANALYSIS

Since plan INFO was specifically designed to deny information to the enemy, the EW officer elects to first examine the information denial aspects of the new plan. He calls up the Information Denial Scores display for plan INFO (Fig. 27).

The information denial score for the previous plan was a mediocre 0.16. The INFO plan results in a score (0.55) appreciably higher than the ALL RADARS OFF score (0.36), and the EW officer justifiably concludes that plan INFO is highly deceptive. To find out why, he calls up the display that compares actual ship value with perceived blip value (Figure 28). He notes that, based solely upon

EMCON PLAN = INFO

INFORMATION DENIED	SCORE
ALL EMITTERS OFF	0.36
CURRENT STATUS	0.55
ALL EMITTERS ON	0.00

Figure 27. Information Denial Scores

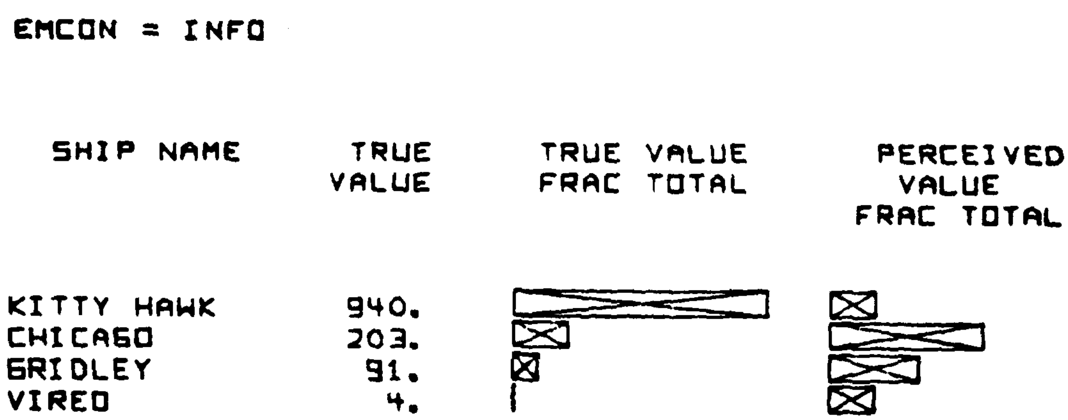


Figure 28. Actual Ship Value and Perceived Blip Value Compared

radar emissions, the Kitty Hawk and Vireo blips are now both perceived as low value ships (a result of the application of guideline 6); that the Chicago blip is now perceived as the highest value ship; and that the Gridley blip is perceived as being about twice as valuable as either the Kitty Hawk or the Vireo blips. He next calls up the display which shows the probability an enemy would assign to the likelihood of a given blip being a given ship (Fig. 29), which should show him why the bar lengths in Fig. 28 have changed so drastically from those shown in Fig. 20 for the former EMCON plan.

The EW officer notes that there is now only a 0.13 probability that the Kitty Hawk blip (A) is being emitted by that ship; this compares to a 0.50 probability of such an association in the previous plan (Fig. 18). There is now a 0.50 probability that the Kitty Hawk blip will mistakenly be assumed to be emitted by the Vireo--primarily as a result of the application of guideline 6.

EMCON PLAN = INFO

BLIP	IDENTIFIED AS	WITH PROBABILITY
KITTY HAWK	KITTY HAWK	0.13
	CHICAGO	0.13
	VIREO	0.50
	GRIDLEY	0.25
CHICAGO	KITTY HAWK	0.50
	CHICAGO	0.50
GRIDLEY	KITTY HAWK	0.25
	CHICAGO	0.25
	GRIDLEY	0.50
VIREO	KITTY HAWK	0.13
	CHICAGO	0.13
	VIREO	0.50
	GRIDLEY	0.25

Figure 29. Probability That a Given Blip is a Given Ship

At this point, the EW officer could elect to call up some of the other information denial displays shown in Section 2.2 above to gain further insights into reasons for the increased deceptiveness of EMCON plan INFO; instead, he elects to examine the effects of this plan on surveillance coverage.

3.2 SURVEILLANCE ANALYSIS

The EW officer first examines the surveillance scores for EMCON plan INFO (Fig. 30). As was to be expected, turning off the Kitty Hawk's SPS-30 and SPS-52 radars resulted in decreased surveillance coverage; however, the surveillance score decrease (from 0.53 under the previous plan to 0.34 for plan INFO)

EMCON PLAN = INFO

SURVEILLANCE SCORE----INTERCEPTION PROBABILITIES

THREAT NAME	INTERCEPTION PROBABILITY CURRENT PLAN	ALL ON	WEIGHT
RATTLER	0.48	0.70	0.50
DRAGON	0.20	0.47	0.50
SCORE	0.34	0.58	

Figure 30. Surveillance Score: Interception Probabilities

was more than the EW officer had anticipated. Figure 31, when compared to the similar display (Fig. 10) for the previous plan, shows a dramatic shift of the probability-of-detection contours inward from the west, which results in a marked degradation of the task force commander's ability to protect the Kitty Hawk from attacks directed at that ship. Figure 32, when compared to the similar display (Fig. 9) for the previous plan shows the reduced radar coverage resulting from turning off the Kitty Hawk's SPS-30 and SPS-52 radars. This decreased coverage caused the inward movement of the probability-of-detection contours, which in turn resulted in the lower surveillance score. To determine the effects of the reduced surveillance coverage afforded by plan INFO in a "worst case" scenario--where the enemy knows the exact location of each task force ship--the EW officer examines the "Surveillance Strike" display (Fig. 33) for the more severe (Dragon) threat. He notes about a 23 percent reduction in "task force surviving," when compared to the similar display (Fig. 12) for the previous plan.

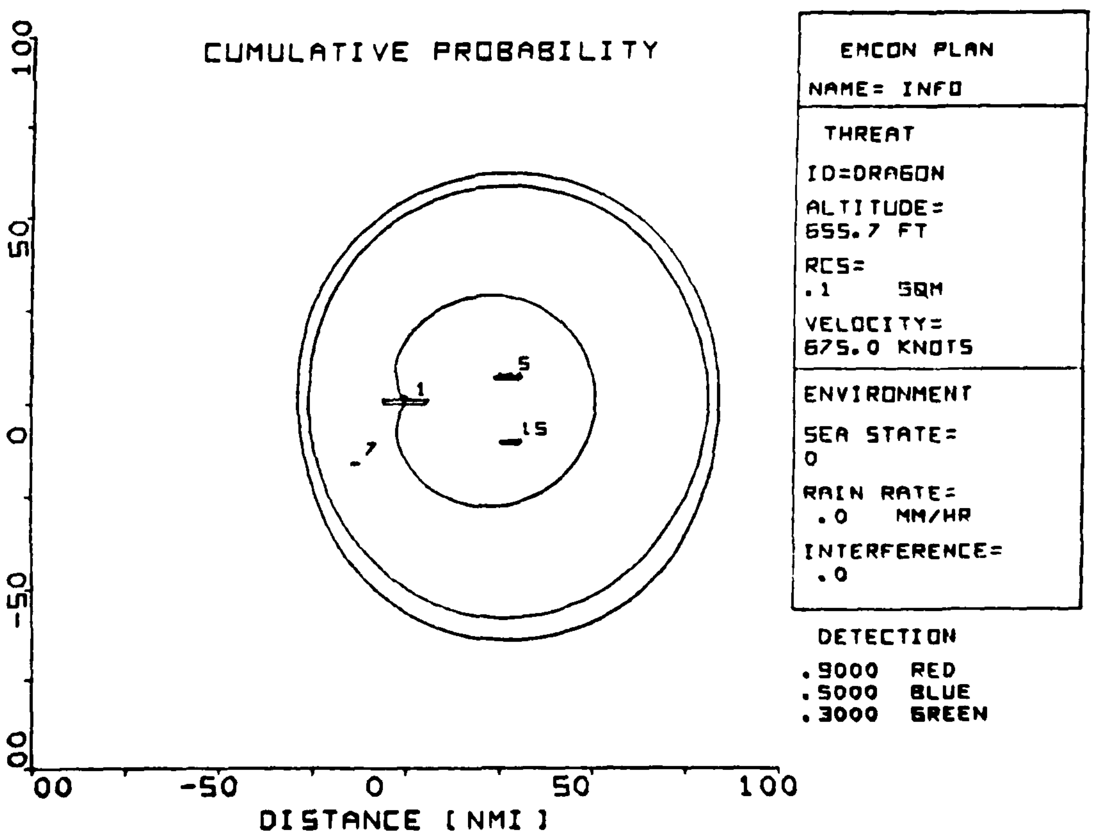


Figure 31. Probability-of-Detection Contours

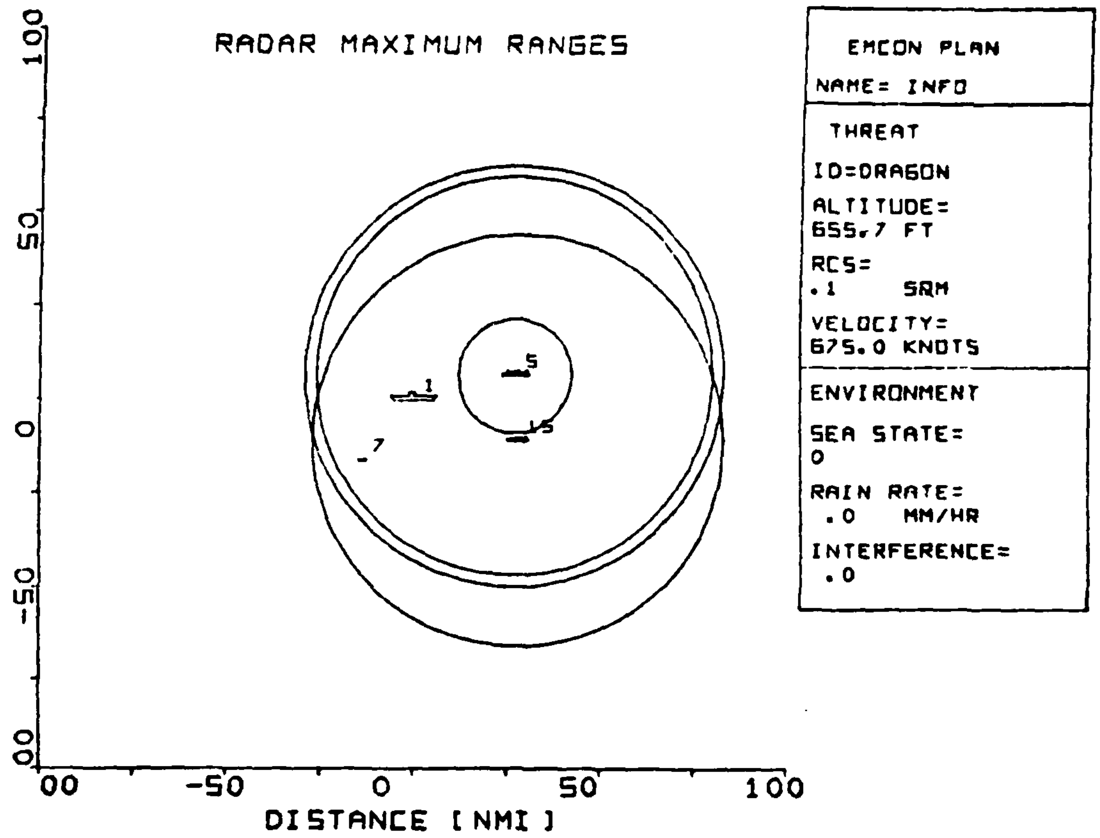


Figure 32. Search Radar Maximum Detection Range Map

OPTIMAL STRIKE
ATTACKER KNOWS SHIP IDENTITY
FRACTIONAL VALUE REMAINING = 0.339
EMCON PLAN = INFO

THREAT	SHIP	ALLO- CATION	PEN. PROB.	# HITS	FRACTION REMAIN	SHIP INIT	VALUE REMAIN
DRAGON	KITTY HAWK	9	0.888	7.4	0.16	939.5	151.8
	CHICAGO	1	0.534	0.3	0.85	203.5	173.4
	VIREO	0	---	--	--	3.7	3.7
	GRIDLEY	0	---	--	--	90.7	90.7
TOTALS		10	--	7.7	--	1237.4	419.6

Figure 33. Surveillance Strike Results

3.3 TRADE-OFF ANALYSIS

The EW officer next examines the display (Fig. 34) which shows expected task force value surviving when the enemy must "guess" ship identities based soley upon emissions from task force radars. He first notes the information denial value of EMCON plan INFO--the difference (659.1) in task force value surviving in the case where the attacker must guess ship identities based on radar emissions (1078.7 in Fig. 34) and in the case where he knows the ship identities (419.6 in Fig. 33). The difference in surviving task force value is primarily attributable to the fact that the Kitty Hawk is so well "hidden" that the enemy allocates none of his missiles to the Kitty Hawk blip (A).

Next, the EW officer compares the task force survival results in Fig. 34 with those for the previous EMCON plan (Fig. 24) and notes that the new plan--merely as a result of careful application of the six information denial guidelines--projects more than a 60 percent increase in surviving task force value against the more severe (Dragon) threat. He makes a similar comparison (not shown here) for the Rattler missile threat, with comparable results.

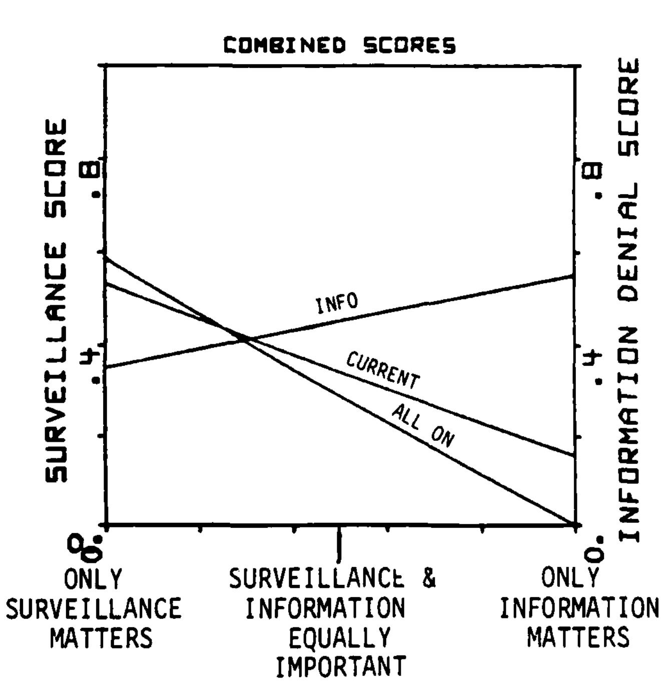
OPTIMAL STRIKE
ATTACKER GUESSES SHIP IDENTITY
FRACTIONAL VALUE REMAINING = 0.872
EMCON PLAN = INFO

THREAT	SHIP	ALLO-CATION	PEN. PROB.	# HITS	FRACTION REMAIN	SHIP INIT	VALUE REMAIN
DRAGON	KITTY HAWK	0	--	--	--	939.5	939.5
	CHICAGO	8	0.534	2.7	0.28	203.5	56.5
	VIREO	0	--	--	--	3.7	3.7
	GRIDLEY	2	0.573	0.6	0.87	90.7	79.0
TOTALS		10	--	3.3	--	1237.4	1078.7

Figure 34. Task Force Value Surviving

Finally, the EW officer examines the "Combined Surveillance and Information Denial Score" display (Fig. 35) for a better understanding of the surveillance-denial profiles of each of three plans--the "current" plan, plan INFO, and the ALL RADARS ON plan. He recognizes the fact that--even though EMCON plan INFO projects significantly better task force survival prospects than does the ALL RADARS ON* plan--the task force commander might prefer the latter plan if he considers surveillance coverage to be much more important than information denial. For example, if the task force commander believes surveillance is much more important than information denial, he might reasonably prefer the ALL RADARS ON plan (Entering the graph in Fig. 35 toward the left of the horizontal scale, and moving directly upwards: the ALL RADARS ON plan dominates plan INFO). However, in the absence of such guidance, the EW officer concludes that plan INFO is the best of these three plans.

*The "task force value surviving" result for the ALL RADARS ON case is 0.558.



EMCON ALTERNATIVES	PURE SCORES SV.	EW
INFO	.35	.55
CURRENT	.53	.16
ALL ON	.59	.00

Figure 35. Combined Surveillance and Information Denial Scores

3.4 FURTHER PLAN DEVELOPMENT

The EW officer is not satisfied merely with having developed a plan which appears to be better than the "current" one. He moves next to steps 6 and 7 in the "Suggested Procedure" table (Fig. 25) to see what the prospects are for further improvements.

A careful examination of the information denial aspects of EMCON plan INFO convinces him there is little likelihood that he can develop a more deceptive plan; such will often be the case when there is complete compliance with the six information denial guidelines. However, the EW officer's analysis of surveillance coverage afforded by plan INFO indicated that there were opportunities for improving such coverage without completely negating the deceptiveness of that plan. He knows (from Figs. 31 and 32) that more radar coverage is needed to the west, and that additional coverage in that area can only come from radars aboard the Kitty Hawk. He also knows the effects (from the "current" EMCON plan) of turning on the SPS-30/SPS-52 pair of radars, so he elects instead to turn on the SPS-43; he designates this plan INFO + KH (for Kitty Hawk) 43, and he completes his evaluation in accordance with steps 3 through 5 of the suggested procedure. This step-by-step evaluation is not reproduced here, but some of the more interesting results from INFO + KH 43 are shown in Figs. 36 and 37, along with the comparable results for an ALL RADARS ON plan, the "current" EMCON plan, and plan INFO.

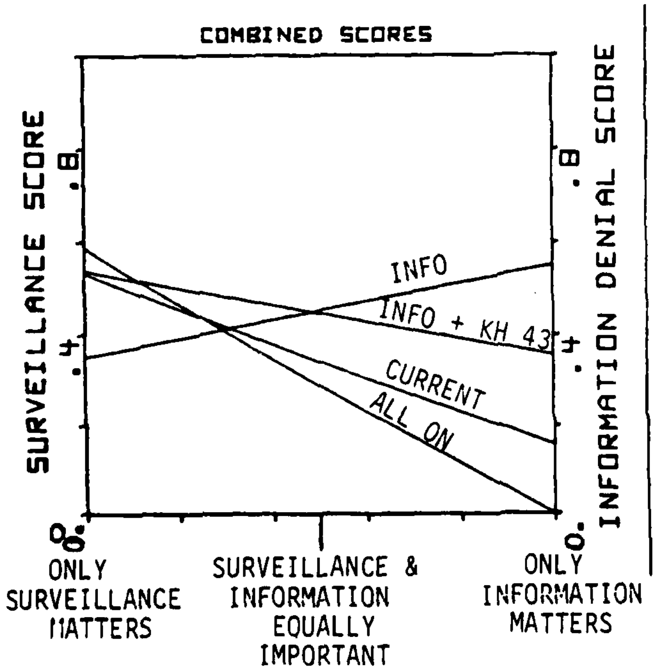
	All Radars On	Current	INFO	INFO+ KH 43
Surveillance Score	0.59	0.53	0.35	0.54
Information Denial Score	0.00	0.16	0.55	0.36
Probability assigned to the Kitty Hawk blip being emitted by the Kitty Hawk	1.00	0.50	0.13	0.25
Information Denial Guidelines complied with	2,3	1,2,3,4	All	1,2,3,4
Surveillance Strike (task force value surviving)				
• Dragon threat	0.475	0.439	0.339	0.443
• Rattler threat	0.640	0.595	0.446	0.600
• Average	0.558	0.517	0.392	0.521
Task Force Value Surviving				
• Dragon threat	0.475	0.538	0.872	0.708
• Rattler threat	0.640	0.672	0.903	0.904
• Average	0.558	0.605	0.888	0.806

Figure 36. A Comparison: Some Results

An examination of these two displays (Figs. 36 and 37) demonstrates the importance of the guidance provided to the EW officer by the task force commander. Consider, for example, the following kinds of guidance and the probable plan selection based upon that guidance:

- "*I want to maximize task force value surviving.*" Select plan INFO for an "average" threat or a Dragon threat; select either INFO or INFO + KH 43 for a Rattler threat.
- "*I want the best hedge against a 'worst case' scenario.*" Select ALL RADARS ON.
- "*I am not comfortable with your 'task force value surviving' projections*; and
- "*Surveillance is my primary concern, but I also want some deception.*" Select INFO + KH 43.
- "*I want the most deceptive plan.*" Select INFO.
- *Etc.*

Note that these displays contain or reflect quantitative data that are especially useful in supporting an EMCON plan decision which is made in response to definitive guidance. In the absence of such guidance, these data are perhaps equally useful because they can provide those insights necessary to develop alternative EMCON plans for the purpose of soliciting firm guidance.



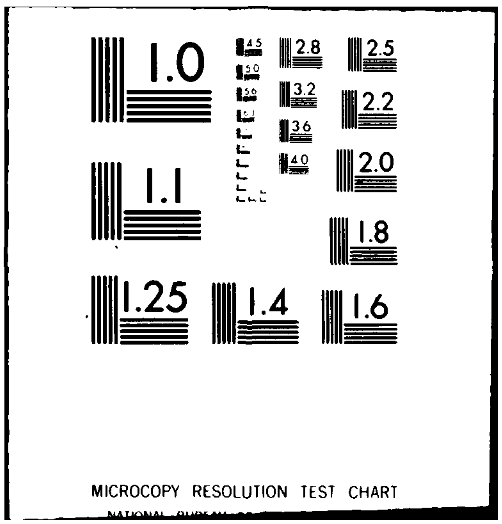
EMCON ALTERNATIVES	PURE SCORES SV.	EW
INFO	.35	.55
CURRENT	.53	.16
INFO+KH43	.54	.36
ALL ON	.59	.00

Figure 37. Combined Surveillance and Information Denial Scores

AD-A087 358 DECISION-SCIENCE APPLICATIONS INC ARLINGTON VA F/G 17/9
DEVELOPMENT AND EVALUATION OF AN EMISSIONS CONTROL DECISION AID--ETC(U)
JUL 80 D F NOBLE, G F PUGH, J E DENSMORE N00014-77-C-0322
UNCLASSIFIED DSA-246 NL

2 of 2
AD A
087358

END
DATE
FILMED
9-80
DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

4.0 SUMMARY FOR TEST SUBJECTS

There is a fundamental trade-off between surveillance--the ability to detect an attacker--and information denial--denying the enemy information about task force dispositions. The development of task force radar utilization plans that balance surveillance coverage against information denial in order to afford the greatest degree of protection to the task force is called the "emissions control" (EMCON) problem.

The Electronic Warfare (EWAR) decision aid has been developed to assist the EW officer in constructing and evaluating EMCON plans. The decision aid performs the quantitative calculations necessary for an evaluation of alternative EMCON plans, and provides graphic displays which highlight weaknesses in EMCON plans and which suggest modifications to improve these plans.

The application of the six information denial guidelines developed for the EWAR decision aid insures a highly deceptive EMCON plan in those situations where the task force radar order-of-battle permits such deception.

The surveillance, information denial, and trade-off displays in the decision aid enable the EW officer to analyze EMCON plans in great detail without having to struggle with the mathematics involved. The trade-off displays provide various bases for evaluating alternative EMCON plans.

The use of the EWAR decision aid insures a logical, structured approach to the resolution of an EMCON problem, and provides a firm basis for evaluating the quantitative aspects of a given plan.

5.0 COMPUTER COMMANDS FOR GENERATING EWAR DISPLAYS

The computer commands for generating the EWAR decision aid displays described in this manual are shown in Fig. 38. The second column in the figure contains a brief description of the display, and the third column references one or more figures in the text of this manual that illustrate the display.

Commands for the displays showing task force disposition (Fig. 1, text), task force ship names, identification numbers, and values (Fig. 6), and threat characteristics (Fig. 7) are not shown in Fig. 38. Handouts for test subjects will include the information contained in these displays.

Figure 38

EWAR Decision Aid Commands

Command	Description of Display	Illustrative Figure(s)
Order-of-Battle		
DISPLAY, EMCON PLAN	Task Force search radar order-of-battle and which radars are on/off for an EMCON plan	5, 14, 26
Surveillance		
SURV, RANGE	Lists radar maximum detection ranges for each task force radar against each threat system	8
SURV, COVERAGE, THR=Threat Name	Plots maximum detection range circles for each emitting search radar for the specified threat	9, 32
SURV, CUMULATIVE, THR=Threat Name	Plots cumulative probability-of-detection contours for the specified threat	10, 31
SURV, SCORE	Displays surveillance scores for each threat system and for an average system	11, 30
SURV, STRIKE, Strike Name	Displays results of a simulated "surveillance" strike (enemy knows which blips are which ships)	12, 33
Information Denial		
INFO, WHO	Lists all ships which could plausibly be assigned to each blip	16
INFO, WHO, SHIP=Blip Name	Lists all ships which could plausibly be assigned to specified blip	16

Figure 38--EWAR Decision Aid Commands (continued)

Command	Description of Display	Illustrative Figure(s)
Information Denial (cont.)		
INFO, WHERE	Lists all blips that an attacker may think is each task force ship, based solely on radar emissions	17
INFO, WHERE,SHIP=Ship Name	Lists all blips that an attacker may think is the specified ship	17
INFO, DETAILS	Lists probabilities that each blip is being emitted by each task force ship	18, 29
INFO, DETAILS, SHIP=Ship Name	Lists probabilities that each blip is being emitted by the specified ship	18, 29
INFO, SUMMARY	Lists probabilities that each ship will be correctly identified (i.e., associated with its blip)	19
INFO, SUMMARY, SHIP=Ship Name	Shows probability that the specified ship will be correctly identified	19
INFO, TARGET	Compares "actual" ship values with "perceived" blip values	20, 28
INFO, SCORE	Shows the information denial score for the EMCON plan being evaluated and for the ALL RADARS ON and ALL RADARS OFF reference plans	21, 27

Figure 38--EWAR Decision Aid Commands (continued)

Command	Description of Display	Illustrative Figure(s)
Trade-off Commands		
TRADE, MAP, THR=*Threat Name*	Plots cumulative probability-of-detection contours for the specified threat and draws blip "perceived" value lines below ship symbols	22
TRADE, SCORES	Plots surveillance and information denial scores which have been "saved" (Command is SAVE, SCORES for a given EMCON plan)	23, 35, 37
TRADE, STRIKE, *Strike Name*	Displays results of a simulated "tradeoff" strike (enemy must infer blip identities based upon radar emission data)	24, 34

Operational Commands	Effect
ON, RAD=*Radar Name*, SHIP=*Ship Name*	Turns on the specified radar on the specified ship
ON, RAD=ALL, SHIP=*Ship Name*	Turns on all radars on the specified ship
ON, RAD=*Radar Name*, SHIP=ALL	Turns on specified radar on all ships
ON, RAD=ALL, SHIP=ALL	Turns on all radars
OFF, RAD=*Radar Name*, SHIP=*Ship Name*	Turns off the specified radar on the specified ship
OFF, RAD=ALL, SHIP=*Ship Name*	Turns off all radars on the specified ship

Figure 38--EWAR Decision Aid Commands (continued)

Operational Commands (cont.)	Effect
OFF, RAD=Radar Name, SHIP=ALL	Turns off specified radar on all ships
OFF, RAD=ALL, SHIP=ALL	Turns off all radars
ON, (or OFF,) RAD=First Radar Name/Second Radar Name/Third Radar Name, SHIP=Ship Name	Turns on (or off) more than one radar aboard the specified ship
ON, (or OFF,) RAD=Radar Name, SHIP=First Ship Name/Second Ship Name/Third Ship Name	Turns on (or off) the specified radar aboard more than one ship
SAVE, EMCON Plan Name	Saves specified EMCON plan
GET, EMCON Plan Name	Sets all task force radars as specified by the EMCON plan named

APPENDIX B

PROCEDURE FOR MANUAL EMCON EVALUATION

DSA Report No. 132

PROCEDURE FOR MANUAL EMCON EVALUATION

D. F. NOBLE
M. T. NUNENKAMP

prepared under contract N00014-77-C-0322

9 April 1979

DECISION-SCIENCE APPLICATIONS, INC.
1500 WILSON BOULEVARD, SUITE 810, ARLINGTON, VIRGINIA 22209

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

This paper includes information and calculation methodology which should be useful to test subjects participating in that part of the University of Pennsylvania effectiveness test program which deals with the manual development of emission control (EMCON) plans. This information and these methodologies are needed to reasonably approximate results that can be obtained using the Electronics Warfare (EWAR) decision aid developed by DSA; thus, the material included in this paper can be given to test subjects who must develop EMCON plans without the assistance provided by the EWAR aid.

We are not necessarily suggesting that all test subjects must attempt the calculations described here; clearly, some subjects simply will not have the mathematical background required, while others may prefer to approach the problem in a more intuitive/less quantitative manner. Thus, our intention is not to force this methodolgy on the test subjects; rather, we felt an obligation to briefly explain the mathematics involved so that those test subjects who were inclined to do so could use them.

Background information--including an explanation of the EMCOM problem and of the exemplar scenario--is contained in DSA Report #126/1, Manual for Test Subjects Using the Electronic Warfare (EWAR) Decision Aid, March 28, 1979; it is not duplicated in this paper.

2.0 OVERVIEW

Section 3.0 shows order-of-battle type information needed by test subjects as a basis for analyzing the potential effectiveness of various EMCON plans. Section 4.0 illustrates methods for quantifying the degree of surveillance/air defense protection afforded a naval task force by a given EMCON plan, and Section 5.0 suggests methods for determining how an enemy would plan his attack, based upon the information he can gather from task force radar emissions. Finally, Section 6 suggests one method

for evaluating an EMCON plan, based upon the surveillance protection provided and the amount of information made available to a potential enemy by task force radar emissions.

3.0 ORDER-OF-BATTLE INFORMATION

The information in Figs. 1 through 6 would be needed by a test subject who attempted to duplicate the calculations shown in Sections 4.0, 5.0, and 6.0 below.

- Figure 1 shows task force dispositions related to the nautical mile scales on the X and Y axes.
- Figure 2 shows which kinds of radars are aboard which task force ships.
- Figure 3 lists the values assigned to each task force vessel for the purposes of the test.
- Figure 4 shows threat characteristics and capabilities.
- Figure 5 lists maximum detection ranges for each task force radar type for each threat system.
- Figure 6 shows the current EMCON plan; i.e., which of the task force radars are turned on/off.

4.0 ESTIMATING RADAR SURVEILLANCE COVERAGE, THREAT PENETRATION PROBABILITIES, AND DAMAGE TO THE TASK FORCE

This section and the two following ones discuss the quantitative approach for evaluating EMCON plans which is the basis of the Electronics Warfare (EWAR) decision aid. A test subject who uses this approach, and who understands what he is doing, can reasonably approximate the results obtainable using the EWAR aid.

The quantitative approach suggested here normally proceeds in six sequential steps. Before initiating this procedure, one must

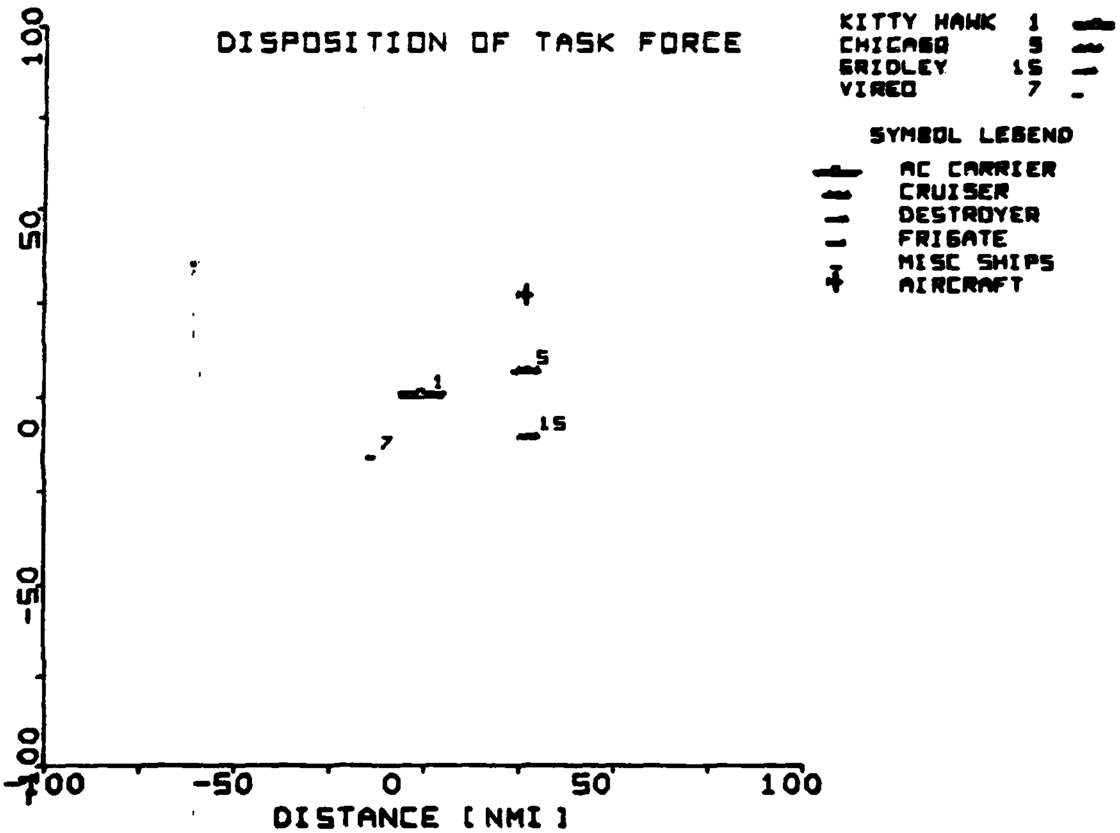


Figure 1. Task Force Disposition

SHIP	SPS-10	SPS-30	SPS-43	SPS-48	SPS-52	SPS-37
Kitty Hawk	X	X	X		X	
Chicago	X	X	X	X	X	
Gridley	X		X	X		
Vireo	X					

Figure 2. Radar Types Aboard Ships

INDEX	SHIP	VALUE
1	Kitty Hawk	939.535
5	Chicago	203.488
7	Vireo	3.721
15	Gridley	90.698

Figure 3. Task Force Ship Names, Identification Numbers, and Values.

THREAT ID	DRAGON
ALTITUDE	655 ft
VELOCITY	675 kts
WEAPON YIELD#	25
WEAPON CEP*	0.03 nmi

#A normalized measure which relates the destructive capability of a weapon to the kind of target against which it is being used.

*CEP is a measure of weapon accuracy.

Figure 4. Threat Characteristics for Dragon Missile

	RATTLER	DRAGON
SPS-43	64.	54.
SPS-48	63.	53.
SPS-10	7.	6.
SPS-30	18.	15.
SPS-52	63.	53.
SPS-37	64.	54.

Figure 5. Task Force Search Radar Maximum Detection Ranges (Maximum Detection Range in nmi)

SHIP	RADARS ON	RADARS OFF
KITTY HAWK	SPS-10, SPS-30 SPS-52	SPS-43
CHICAGO	SPS-10, SPS-30 SPS-43, SPS-52	SPS-48
GRIDLEY	SPS-10, SPS-43	SPS-37 SPS-48
VIREO	SPS-10	

Figure 6. Status of Radars for EMCON Plan "Current"

estimate the nature of the threat; i.e., how many missiles would the potential enemy allocate to each of the blips appearing on his radar screen. A quantitative procedure for determining the nature of the threat is included in Section 5.0 below.

The six sequential steps are:

1. Plotting maximum detection range circles for task force radars which are turned on.
2. Estimating detection rates within the plotted circles.
3. Calculating approximate cumulative detection probabilities for an attack approaching from a given direction or directions.
4. Calculating the probability that a threat system would penetrate the task force air defenses.
5. Calculating the expected number of hits on task force ships which are targeted.
6. Estimating resulting ship/task force damage.

4.1 MAXIMUM DETECTION RANGE CIRCLES

Figure 7 shows the maximum detection range circles for each emitting active air search radar. This plot is developed using the EMCON plan status table (Fig. 6), the radar maximum range data for the anticipated threat (Fig. 3), and the task force disposition map (Fig. 1). It shows the envelop within which threat detection is possible, and it shows the coverage overlap from these search radars.

4.2 ESTIMATING DETECTION RATES WITHIN RADAR COVERAGE CIRCLES

The detection rate per nautical mile can be approximated by using the formula:

$$P_d/_{nmi} = 57.6 \times \text{number of radars covering a point/threat velocity in knots.}$$

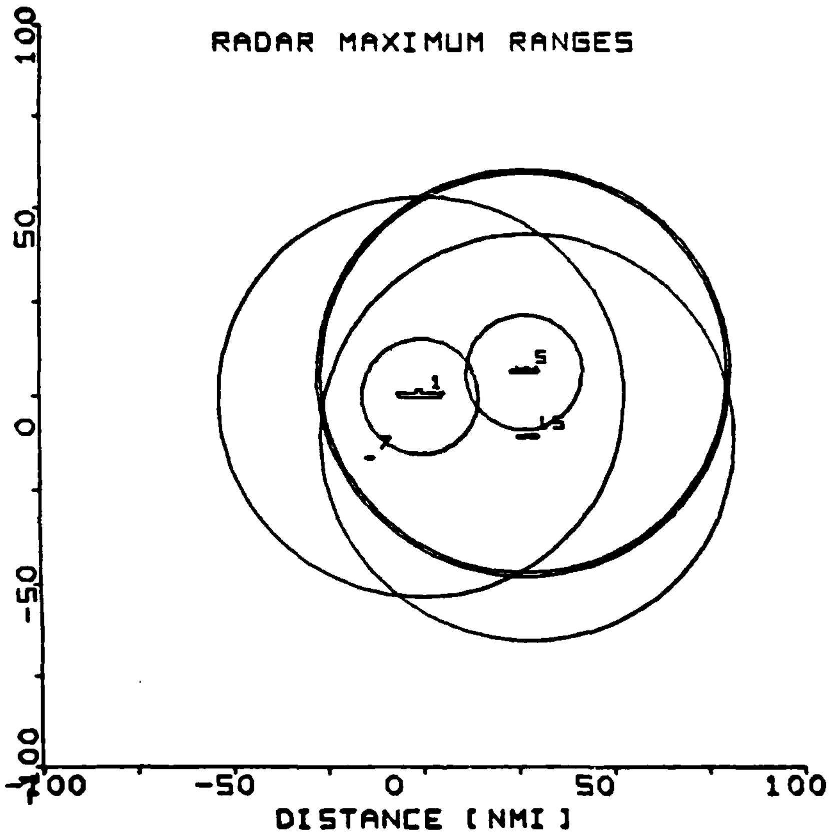


Figure 7. Maximum Detection Range Circles for EMCON Plan "Current" and Threat Dragon

4.3 APPROXIMATING CUMULATIVE DETECTION PROBABILTIES ALONG SELECTED ATTACK ROUTES

The cumulative detection probability depends upon the velocity of the threat system and the direction from which the threat approaches the task force. Therefore, a different function relating cumulative detection probability to distance from the target ship will be associated with each threat type, with each attack approach path, and with each EMCON state. The calculation of cumulative detection probability proceeds in several steps: the selection of an approach path; the computation of the approximate detection rate per nmi along each segment of the approach path; the integration of this rate along the path: and, finally, the conversion from this integral to the cumulative detection probability.

In this example, the objective is to calculate the cumulative probability of detection for a Dragon threat system aimed at the Kitty Hawk and approaching from the west. In Fig. 8, this threat path is superimposed upon the previously drawn radar maximum range plot. As indicated in Table 1--which was developed using the Dragon velocity of 675 knots and the formula P_d/nmi illustrated in Section 4.2 above--a Dragon system further than 53 nmi due West of the Kitty Hawk cannot be detected. The table also shows the increased probability-of-detection rates which result as the Dragon nears the Kitty Hawk and comes within range of additional task force radars. An intermediate step in calculating cumulative detection probability is to integrate P_d along the approach path. The cumulative detection probability P_{cum} is calculated from this integral. If

$$C = \int_{\infty}^{r_o} P_d \; dr$$

then $P_{cum}(r_o) = C/(1 + C)$. Table 2 gives the values of C and P_{cum} at each of the "break" points. Figure 9 plots the integral C(r) against

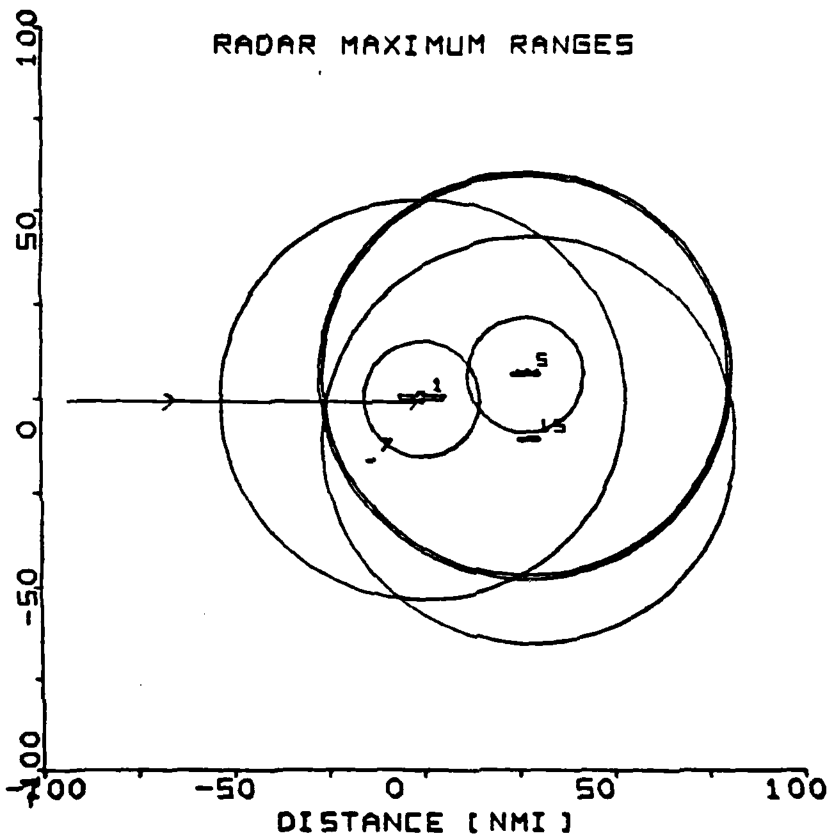


Figure 8. Number of Search Radars Covering Each Leg of an Approach Path

TABLE 1

DETECTION RATE PER NAUTICAL MILE AND THE NUMBER OF SEARCH RADARS COVERING EACH LEG OF THE DRAGON APPROACH PATH

range (nmi)	number of radars covering	P_d/nmi
∞ to 53	0	0
53 to 25	1	0.0853
25 to 15	3	0.2559
15 to 0	4	0.3412

TABLE 2

INTEGRAL OF DETECTION PROBABILITY AND CUMULATIVE DETECTION PROBABILITY ALONG DRAGON APPROACH PATH

range	$C = \int_{\infty}^{r_o} P_d \, dr$	$P_{cum} = C/1 + C)$
53	0	0
25	0 + (53 - 25) x 0.0853 = 2.389	0.7049
15	2.389 + (25 - 15) x 0.2559 = 4.948	0.8318
0	4.948 + 15 x 0.3412 = 10.066	0.91

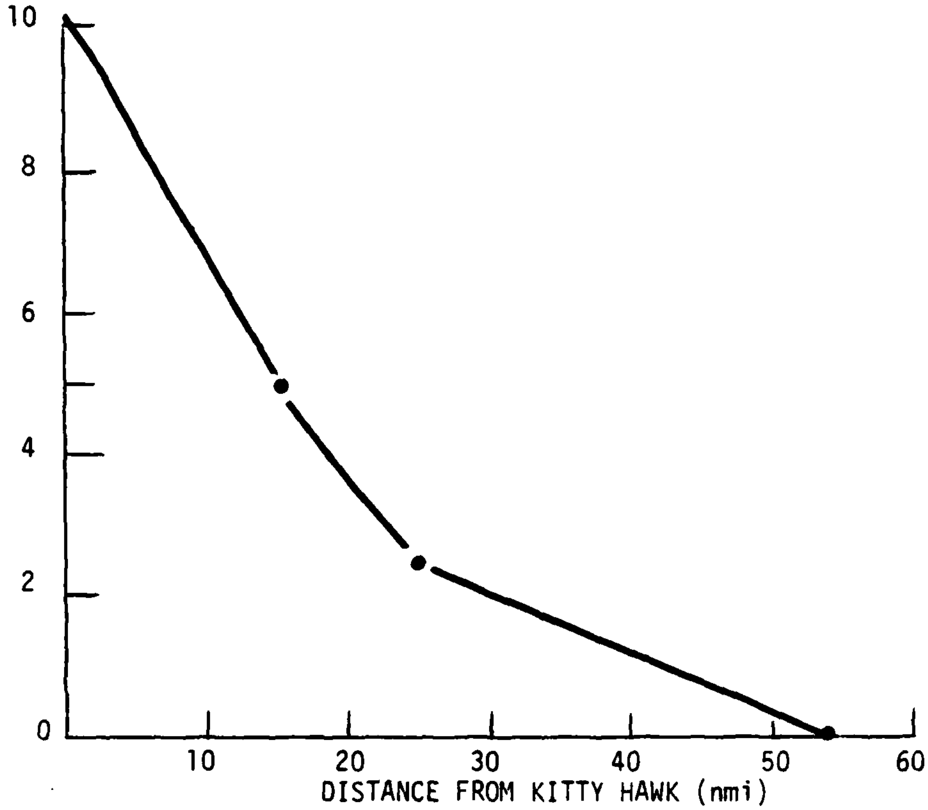


Figure 9. $\int_0^{r_o} P_d dr = C(r_o)$ For Attack by Dragon Along Path From West

distance from the Kitty Hawk, and Fig. 10 shows the desired function of P_{cum} versus range.

4.4 CALCULATING THREAT PENETRATION PROBABILITIES

Successful threat interception requires threat detection and tracking, launch of defense systems, and, finally, threat destruction. The test scenario assumes that the target tracking and anti-threat missile allocation process takes 90 seconds. During that time, the detected threat cannot be destroyed. Thereafter, the task force uses a shoot-look-shoot* doctrine against the threat. In this example, about half of the incoming missiles would be destroyed in the first 125-second period, and 50% of the survivors would be destroyed in each successive 125 second period.

The threat penetration probability consistent with the above assumptions can be estimated using the cumulative detection probability curve (Fig. 10), the penetration probability equation given below, and Fig. 11: which shows how to find the ranges used in the penetration probability equation.

The expression giving threat penetration probability is

$$P_{pen} = 1.0 - 0.25 \times [(0.5 \times P_{cum}(r_1) + P_{cum}(r_2) + P_{cum}(r_3) + P_{cum}(r_4)]$$

In this equation, variables r_1, r_2, r_3, and r_4 are the distances at which a just-detected threat has a 100%, 75%, 50%, or 25% chance, respectively, of successfully penetrating the defense. The values depend on the threat velocity. They may be obtained directly from Fig. 11 by reading the r_1 - r_4 values from the corresponding r_1 - r_4 lines at the appropriate threat velocity.

The probability that threat Dragon will penetrate to the Kitty Hawk along the west-to-east bearing illustrated in Fig. 7 is computed as

---

*Fire at the threat, assess results, then fire again if necessary.

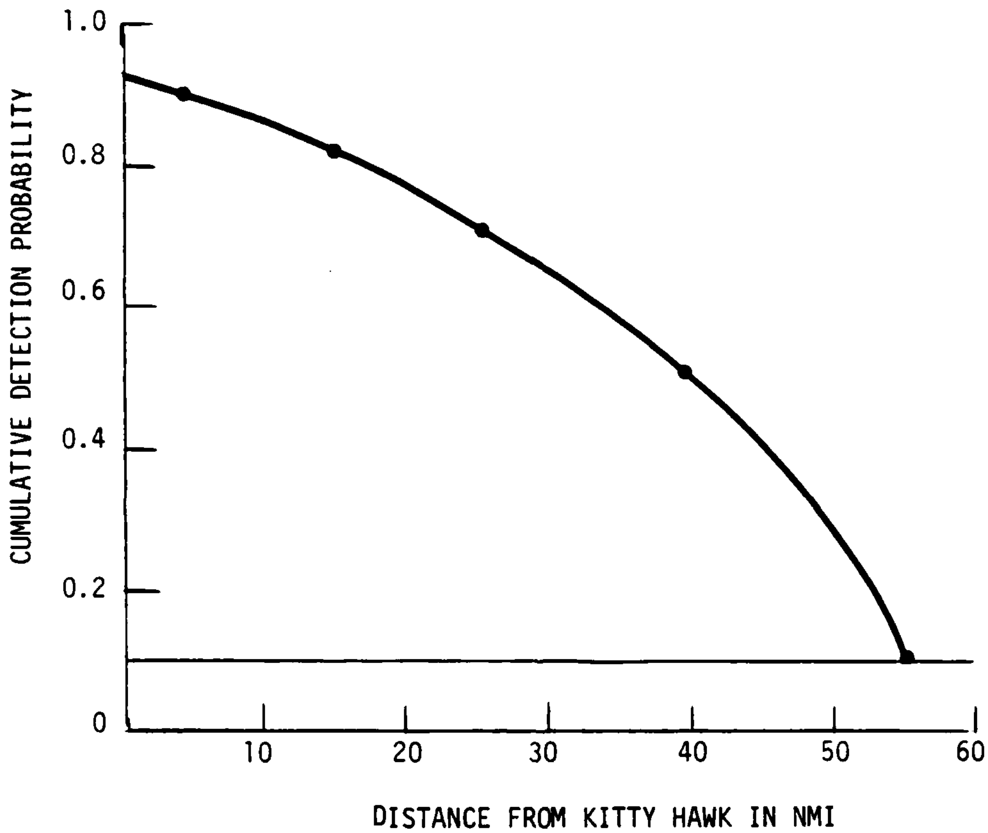


Figure 10. P_{cum} versus Distance for Attack by Dragon Along Path From West

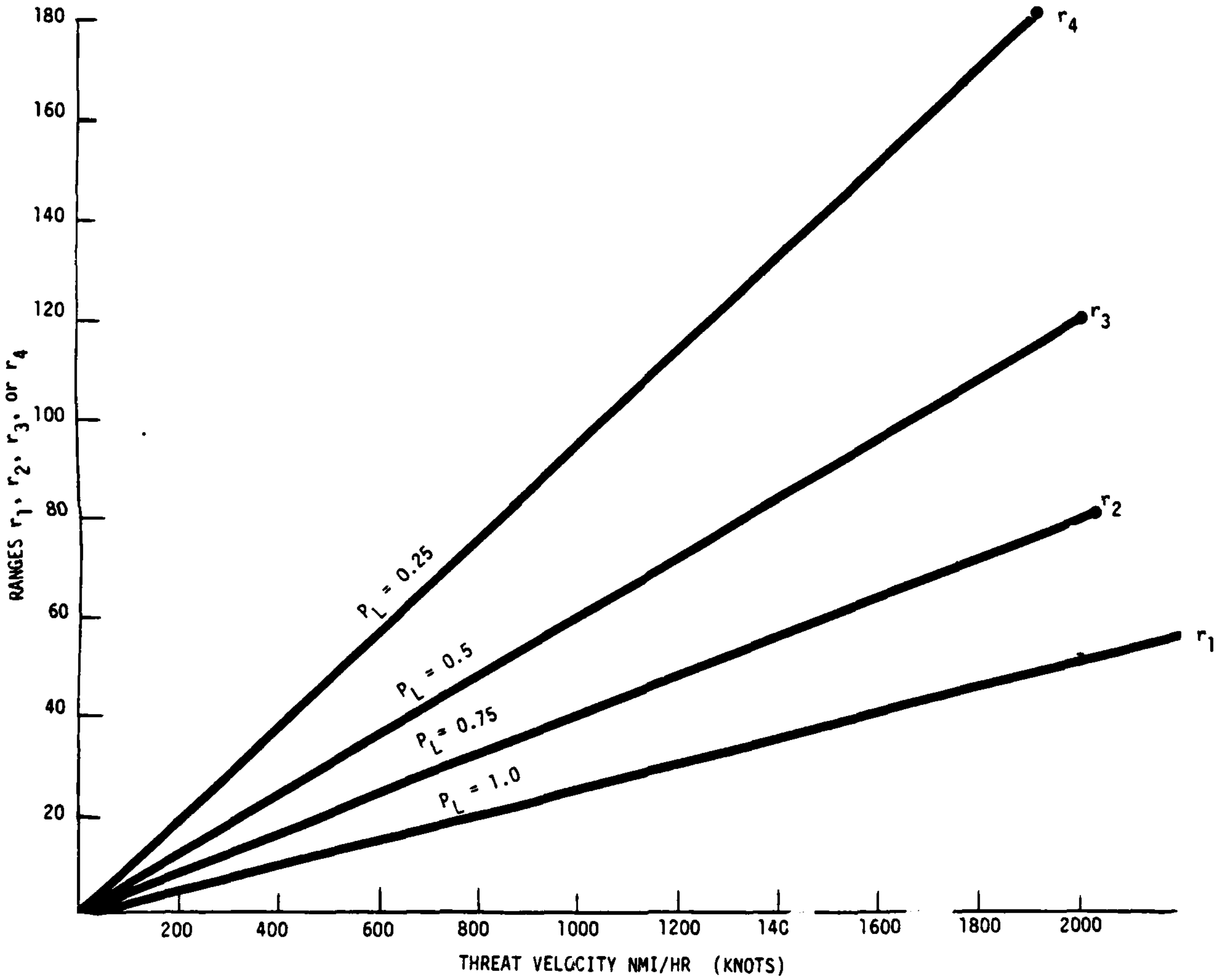


Figure 11. Launch Probability Ranges Required for Computation of Penetration Probability

follows: Since the Dragon missile has a velocity of 675 knots, the values for r_1, r_2, r_3, and r_4 are obtained from Fig. 11 using the velocity value on the x-axis of 675 knots. These ranges and the corresponding cumulative detection probabilities obtained from Fig. 10 are listed in Table 3.

4.5 EXPECTED NUMBER OF HITS AND RESULTANT DAMAGE TO SHIPS

The number of hits received by each ship equals the product of the penetration probability computed in Section 4.4 and the number of weapons allocated to each ship and the probability of hit given penetration.

The probability of a hit, given penetration, depends on the accuracy of the threat and on the size of the target. Threat accuracy is denoted by weapon CEP data included in the threat characteristics listed in Fig. 4. Table 4 lists the probability that a threat with a given accuracy will actually hit its target ship. In this example, threat Dragon has a CEP of 0.03 nmi. Each penetrating Dragon missile has a 0.77 chance of hitting the Kitty Hawk, a number obtained from the Kitty Hawk row and the 0.03 column in Table 4. In this case, if six Dragon missiles targeted on the Kitty Hawk penetrate the ship defense, then about 4.6 of these would be expected to hit that ship.

Damage to the ship depends on the number of hits, the hardness of the ship, and the yield of the weapon. The number of hits was computed above. Weapon yield is a data entry in Fig. 4. For a Dragon missile, the yield is 25 (normalized units). The expected damage to Kitty Hawk when hit by about 4.6 25-yield warheads can be obtained from Table 5a, the damage-versus-hit table appropriate to a weapon with a yield of 25. (Tables 5b and 5c show damage functions for 50-yield and 100-yield warheads, respectively.) Table 5a indicates that four hits would destroy about 63% of the Kitty Hawk value; five hits would destroy 71%. Therefore, 4.6 this would be expected to destroy about 68% of the value.

4.6 SUMMARY

The example in this section was used to show a quantitative approach to the problem of estimating damage likely to be incurred by the task

TABLE 3

CRITICAL RANGES AND CUMULATIVE PROBABILITIES NEEDED FOR PENETRATION PROBABILITY COMPUTATION

Launch probability given first detection at this range	variable	range	P_{cum}
1.0	r_1	17 nmi	0.8
0.75	r_2	27 nmi	0.69
0.50	r_3	40 nmi	0.51
0.25	r_4	63 nmi	0.0

TABLE 4

PROBABILITY OF HIT FOR EACH SHIP

	CEP						
	0.005	0.01	0.02	0.03	0.05	0.07	0.1
BLUE RIDGE	0.097	0.90	0.72	0.54	0.29	0.17	0.09
BOWEN	1.0	0.85	0.55	0.37	0.17	0.09	0.05
CHICAGO	0.97	0.94	0.75	0.57	0.33	0.20	0.11
COCHRONE	0.97	0.85	0.55	0.31	0.17	0.09	0.05
FISKE	0.94	0.79	0.51	0.31	0.14	0.08	0.04
FORRESTAL	1.	0.97	0.88	0.75	0.54	0.37	0.22
FOSTER PF	0.97	0.90	0.68	0.48	0.25	0.15	0.08
GARCIA	0.94	0.82	0.54	0.34	0.16	0.08	0.05
GRIDLEY	0.97	0.87	0.66	0.47	0.24	0.13	0.07
HIGBEE	0.94	0.79	0.51	0.31	0.14	0.08	0.04
HOLT HE	1.	0.85	0.55	0.37	0.17	0.09	0.05
KITTY HAWK	1.	0.97	0.88	0.77	0.54	0.38	0.23
NASTY	0.40	0.15	0.41	0.02	0.31	0.0	0.0
OKLAHOMA	0.97	0.90	0.72	0.52	0.29	0.16	0.08
PONCHATOULA	0.97	0.94	0.75	0.57	0.31	0.19	0.10
ROARK	1	0.85	0.55	0.37	0.17	0.09	0.05
SPRUANCE	0.97	0.90	0.68	0.49	0.25	0.15	0.08
TARAWA	1	0.94	0.82	0.66	0.42	0.27	0.15
TRUETT	1	0.85	0.55	0.37	0.17	0.08	0.05
VIREO	0.68	0.36	0.13	0.06	0.02	0.01	0.005
WIDGEON	0.68	0.36	0.13	0.06	0.02	0.01	0.008

TABLE 5a

DAMAGE. WEAPON YIELD = 25

CEP

#HITS	1	2	3	4	5	6	7	8	9	10
BLUE RIDGE	0.37	0.60	0.75	0.84	0.90	0.94	0.96	0.97	0.98	0.99
BOWEN	0.55	0.80	0.91	0.96	0.98	0.99	1.	1.	1.	1.
CHICAGO	0.37	0.60	0.75	0.84	0.90	0.94	0.96	0.98	0.98	0.99
COCHRANE	0.54	0.79	0.90	0.95	0.98	0.99	1.	1.	1.	1.
FISKE	0.57	0.82	0.92	0.97	0.99	0.99	1.	1.	1.	1.
FORRESTAL	0.22	0.39	0.52	0.63	0.71	0.77	0.82	0.87	0.89	0.92
FOSTER PF	0.47	0.72	0.85	0.92	0.96	0.98	0.99	0.99	1.	1.
GARCIA	0.57	0.82	0.92	0.97	0.99	0.89	1.	1.	1.	1.
GRIDLEY	0.22	0.39	0.52	0.63	0.71	0.77	0.82	0.87	0.89	0.92
HIGBE	0.57	0.82	0.92	0.97	0.99	0.99	1.	1.	1.	1.
HOLT HE	0.55	0.80	0.91	0.96	0.98	0.99	1.	1.	1.	1.
KITTY HAWK	0.22	0.39	0.52	0.63	0.71	0.77	0.82	0.87	0.89	0.92
NASTY	0.91	0.99	1.	1.	1.	1.	1.	1.	1.	1.
OKLAHOMA C.	0.4	0.64	0.78	0.87	0.92	0.95	0.97	0.98	0.99	0.99
PONCHATOULA	0.31	0.52	0.67	0.77	0.44	0.89	0.93	0.95	0.96	0.98
ROARK	0.55	0.80	0.91	0.96	0.98	0.99	1.	1.	1.	1.
SPRUANCE	0.47	0.72	0.85	0.92	0.96	0.98	0.99	0.99	1.	1.
TARAWA	0.28	0.48	0.63	0.73	0.81	0.86	0.90	0.93	0.95	0.96
TRUETT	0.55	0.80	0.91	0.96	0.98	0.99	1.	1.	1.	1.
VIREO	0.85	0.98	1.	1.	1.	1.	1.	1.	1.	1.
WIDGEON	0.85	0.98	1.	1.	1.	1.	1.	1.	1.	1.

TABLE 5b.

DAMAGE. WEAPON YIELD = 50

	CEP									
#HITS	1	2	3	4	5	6	7	8	9	10
BLUE RIDGE	0.49	0.74	0.87	0.93	0.97	0.98	0.99	1.	1.	1.
BOWEN	0.67	0.89	0.96	0.99	1.	1.	1.	1.	1.	1.
CHICAGO	0.48	0.73	0.85	0.93	0.96	0.98	0.99	0.99	1.	1.
COCHRANE	0.65	0.88	0.96	0.98	0.99	1.	1.	1.	1.	1.
FISKE	0.68	0.90	0.97	0.99	1.	1.	1.	1.	1.	1.
FORRESTAL	0.31	0.52	0.67	0.77	0.84	0.89	0.93	0.95	0.86	0.98
FOSTER PF	0.59	0.83	0.93	0.97	0.99	1.	1.	1.	1.	1.
GARCIA	0.68	0.90	0.97	0.99	1.	1.	1.	1.	1.	1.
GRIDLEY	0.31	0.52	0.67	0.77	0.84	0.89	0.93	0.95	0.96	0.98
HIGBEE	0.68	0.90	0.97	0.99	1.	1.	1.	1.	1.	1.
HOLT HE	0.67	0.89	0.96	0.99	1.	1.	1.	1.	1.	1.
KITTY HAWK	0.30	0.51	0.66	0.76	0.83	0.88	0.92	0.94	0.96	0.97
NASTY	0.91	0.99	1.	1.	1.	1.	1.	1.	1.	1.
OKLAHOMA C.	0.51	0.76	0.88	0.94	0.97	0.99	0.99	1.	1.	1.
PONCHATOULA	0.42	0.66	0.81	0.89	0.93	0.96	0.98	0.99	0.99	1.
ROARK	0.67	0.89	0.96	0.99	1.	1.	1.	1.	1.	1.
SPRUANCE	0.59	0.83	0.93	0.97	0.99	1.	1.	1.	1.	1.
TARAWA	0.39	0.62	0.77	0.86	0.92	0.95	0.97	0.98	0.99	0.99
TRUETT	0.67	0.89	0.96	0.99	1.	1.	1.	1.	1.	1.
VIREO	0.88	0.99	1.	1.	1.	1.	1.	1.	1.	1.
WIDGEON	0.88	0.99	1.	1.	1.	1.	1.	1.	1.	1.

TABLE 5c.
DAMAGE. WEAPON YIELD = 100

	#HITS	CEP 1	2	3	4	5	6	7	8	9	10
BLUE RIDGE		0.6	0.84	0.94	0.97	0.99	1.	1.	1.	1.	1.
BOWEN		0.76	0.94	1.	1.	1.	1.	1.	1.	1.	1.
CHICAGO		0.6	0.84	0.94	0.97	0.99	1.	1.	1.	1.	1.
COCHRANE		0.75	0.94	1.	1.	1.	1.	1.	1.	1.	1.
FISKE		0.77	0.95	0.99	1.	1.	1.	1.	1.	1.	1.
FORRESTAL		0.41	0.65	0.79	0.88	0.93	0.96	0.98	0.99	0.99	0.99
FOSTER PF		0.7	0.91	0.99	1.	1.	1.	1.	1.	1.	1.
GARCIA		0.77	0.95	0.99	1.	1.	1.	1.	1.	1.	1.
GRIDLEY		0.41	0.65	0.79	0.88	0.92	0.96	0.98	0.99	0.99	0.99
HIGBE		0.77	0.95	0.99	1.	1.	1.	1.	1.	1.	1.
HOLT HE		0.76	0.94	1.	1.	1.	1.	1.	1.	1.	1.
KITTY HAWK		0.41	0.65	0.79	0.88	0.93	0.96	0.98	0.99	0.99	0.99
NASTY		1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
OKLAHOMA C.		0.62	0.86	0.95	0.98	0.99	1.	1.	1.	1.	1.
PONCHATOULA		0.54	0.79	0.90	0.96	0.98	0.99	1.	1.	1.	1.
ROARK		0.76	0.94	1.	1.	1.	1.	1.	1.	1.	1.
SPRUANCE		0.7	0.91	0.99	1.	1.	1.	1.	1.	1.	1.
TARAWA		0.5	0.75	0.88	0.94	0.97	0.98	0.99	1.	1.	1.
TRUETT		0.76	0.94	1.	1.	1.	1.	1.	1.	1.	1.
VIREO		0.90	0.99	1.	1.	1.	1.	1.	1.	1.	1.
WIDGEON		0.90	0.99	1.	1.	1.	1.	1.	1.	1.	1.

force, given a specific threat. Determining the nature of the specific threat--i.e., how many missiles the enemy would allocate to each of the blips appearing on his radar screen--is obviously an important fact in this damage estimation process. The following section addresses the problem of characterizing the probable nature of the threat.

5.0 INFORMATION PROVIDED THE ENEMY BY TASK FORCE RADAR EMISSIONS

Because the effectiveness of the enemy strike will depend not only on how capable his strike systems are of penetrating task force defenses, but also on how well he succeeds in identifying--and allocating strike systems to--the more "valuable" ships in the convoy, it is evident that denying targeting information to the enemy is an important factor in task force defense. In the test scenarios, it is assumed that the only targeting information available to the enemy is that which can be inferred from his knowledge of task force composition, from the radar order-of-battle for each ship in the task force, and from the pattern of radar emissions he sees on his radar screens. This section outlines two methods for determining the amount of targeting information provided an enemy by an EMCON plan; that is, the amount of such information which can logically be deduced based upon the emissions from task force radars turned on in accordance with that EMCON plan. The first method involves a Bayesian approach which can often be used if the task force is rather small; the second is a more approximate method which can be used in other cases.

5.1 ESTIMATING BLIP IDENTITIES USING THE BAYESIAN APPROACH

When using this method, the EMCON evaluator lists every possible ship-to-blip assignment consistent with the EMCON plan being examined. The probability that a given ship is a given blip is the ratio of the number of legal blip-to-ship assignments (in which the given ship is assigned to this blip) to the total number of legal assignments. For example, for EMCON plan "current", an attacker constructs the following blip pattern:

A. SPS-10 SPS-30 SPS-52	B. SPS-10 SPS-30 SPS-43 SPS-52
C. SPS-10 SPS-43	D. SPS-10

The following ships could be assigned to each blip:

A. Kitty Hawk Chicago	B. Kitty Hawk Chicago
C. Kitty Hawk Chicago Gridley	D. Kitty Hawk Chicago Gridley Vireo

Using these assignments, the planner lists all task force ship-to-blip assignments consistent with this EMCON plan.

Assignment	Blip A	Blip B	Blip C	Blip D
1	Kitty Hawk	Chicago	Gridley	Vireo
2	Chicago	Kitty Hawk	Gridley	Vireo

In this case, there are only two legal assignments. In half the assignments the Kitty Hawk is assigned to blip A; in the other half it is assigned to blip B. Therefore, the planner concludes that the enemy will think there is a 50% chance that blip A is emitted by the Kitty Hawk and a 50% chance that it is emitted by the Chicago. He will assign the same probabilities to blip B. Therefore, he is likely to divide those missiles intended for Kitty Hawk equally between blips A and B. For more complicated scenarios, the manual computation of Bayesian probabilities may not be feasible, because there may be several thousand legal assignments. In such cases, an alternative "approximation" method can be used.

5.2 APPROXIMATION METHOD

In this method, the planner lists the ships that can be assigned to each blip. Next to each blip-ship combination he notes a "probability" for the occurrence of this combination (which is derived by dividing 1.00 by the number of blips to which he could assign this ship). The probability that a blip was emitted by each plausibly assigned ship is equal to this derived probability divided by the sum of the probabilities associated with all blip-ship combinations for this blip.

For the example previously computed, such an assignment table would appear as follows:

A.	Kitty Hawk	0.25	B.	Kitty Hawk	0.25
	Chicago	0.25		Chicago	0.25
C.	Kitty Hawk	0.25	D.	Kitty Hawk	0.25
	Chicago	0.25		Chicago	0.25
	Gridley	0.5		Gridley	0.5
				Vireo	1.0

Then the estimated probability that the Kitty Hawk is emitted by each blip is

blip	probability
A	0.25/(0.25 + 0.25) = 0.5
B	0.25/(0.25 + 0.25) = 0.5
C	0.25/(0.25 + 0.25 + 0.5) = 0.25
D	0.25/(0.25 + 0.25 + 0.5 + 1) = 0.125

In this case, the attacker would assign about 35% of his attackers to A, 35% to B, 20% to C and 10% to D.

Assignments based on this method are less accurate than those derived from the Bayesian analysis. However, this procedure is likely to remain feasible for all scenarios and EMCON plans considered. It should be used whenever the use of the Bayesian method is not feasible.

5.3 BLIP VALUE CALCULATION

An attacker will assign a priority to attacking each blip. One method for determining the importance of each blip is to assign it a value. This value can be computed as follows:

Value of Blip A = Value ship 1 x probability Blip A is emitted by ship 1
+ Value ship 2 x probability blip A is emitted by ship 2
+ ...

Value of Blip B = Value of ship 1 x probability blip B is emitted by ship 1
+ ...

In this example,

Value of Blip A = value of Kitty Hawk x probability blip A was emitted by Kitty Hawk + value of Chicago x probability blip A was emitted by Chicago = 940 x 0.5 + 204 x 0.5 = 572.

Blip B also has a value of 572 under EMCON plan "current". Blips C and D have much lower values.

5.4 SUMMARY

Bayesian probability theory is the basis for that part of the EWAR decision aid which quantifies the usefulness to the enemy of targeting information provided by radar emission patterns. In order to duplicate results obtainable using the EWAR aid, test subjects have to be able to make the basic calculations themselves. This section has shown the procedures for making such calculations; however, these procedures can

only be used for rather small task forces, since required calculations for larger task forces would be beyond the test subjects' abilities to complete within any reasonable period of time. In the event that such "larger" task forces are used in testing scenarios, an alternative rough-approximation procedure which can be used for larger task forces has also been shown in this section.

6.0 DERIVING ESTIMATED DAMAGE TO THE TASK FORCE

Based upon the assumption that a rational enemy would attempt to maximize the total amount of task force "value" destroyed, test subjects can develop enemy weapon allocations based upon the probabilities developed in Section 5.0, then calculate expected damage to the task force as suggested in Section 4.0. The amount of task force value surviving such a rational attack is one measure of the utility of a given EMCON plan.

Under EMCON plan "current", the Dragon strike kills a total of 512 in task force value. By comparing this amount to the values destroyed with other EMCON plans, the planner can select a "best" EMCON plan.

In our example, blip A (emitted by Kitty Hawk) and blip B (emitted by Chicago) are equally valued, and considered to be much more important targets than blips C or D. An attacker with 10 Dragon missiles to allocate would probably direct five to blip A (Kitty Hawk) and five to blip B (Chicago). Those directed to blip A would probably follow the west-to-east path analyzed in Section 4.0. About three of those five Dragons would penetrate the defense. Those directed to blip B would probably approach from the northeast. Given the similarity between the radar fields traversed by the paths to blips A and B, the penetration probability to blip B is likely to be about 0.5. About 2.5 of these 5 Dragon missiles should penetrate to the Chicago.

Table 4 suggests that about 3 x 0.77 Dragon missiles would hit the Kitty Hawk, and that about 2.5 x 0.68 missiles would hit the Chicago. The total damage to the task force is the damage to Kitty Hawk plus the damage to Chicago. Table 6 summarizes these results. The "fraction damage" is the interpolated expected damage using Table 5a for Kitty Hawk and Chicago.

APPENDIX C

SCENARIO 1 - 15

TABLE C-1

SHIPS INCLUDED IN CANDIDATE TASK FORCE CONFIGURATIONS

MASTER SCENARIO CHART

		11C31	12B01	12B01	25B00	23B30	10450	10A51	11A30	11C32	12A13	10C21	12C40	13B11	13B22	20*22
	Scenario	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Kitty Hawk	X		X	X	X	X	X			X		X	X		X
21	Forrestal		X		X	X			X	X		X			X	X
16	Tarawa															
20	Blue Ridge		X													
5	Chicago	X		X	X	X					X		X	X	X	
6	Oklahoma City		X	X	X	X			X	X				X	X	
2	Spruance		X	X			X			X			X			
18	Foster PF						X		X						X	
19	Cochrane							X		X	X	X	X			
12	Fiske		X					X							X	
17	Higbee							X	X							
15	Gridley	X			X	X					X		X	X	X	
4	Truett			X			X							X		X
9	Bowen						X		X				X			X
10	Holt HE			X												X
11	Roark					X	X	X				X				
13	Garcia					X		X		X			X			
14	Ponchatoula													X	X	X
7	Vireo	X								X	X					
8	Widgeon							X			X				X	
3	Nasty		X							X	X	X				
Number of Ships		4	6	6	5	7	6	7	5	7	7	4	7	6	8	6

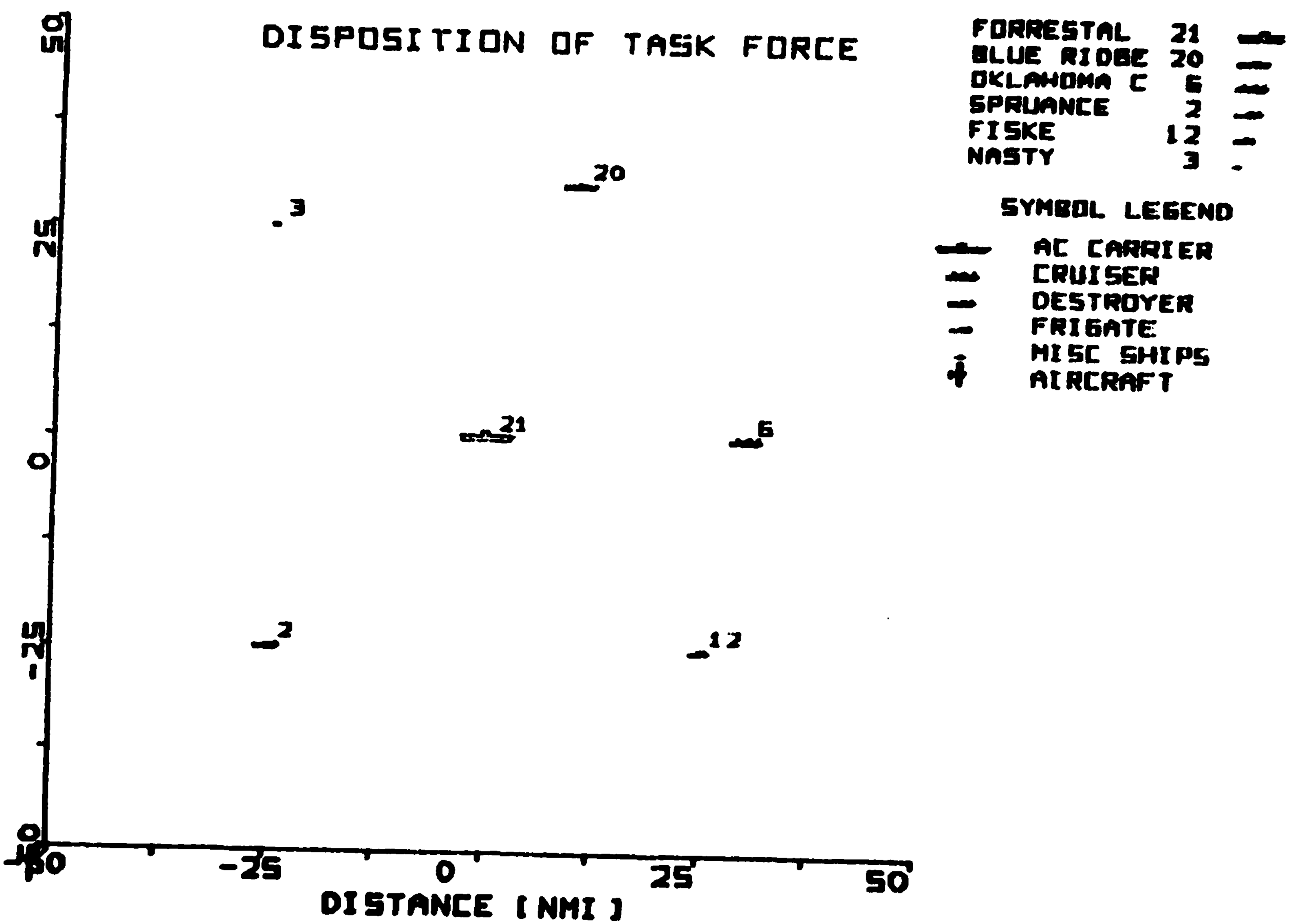


Figure C-1. Scenario 1

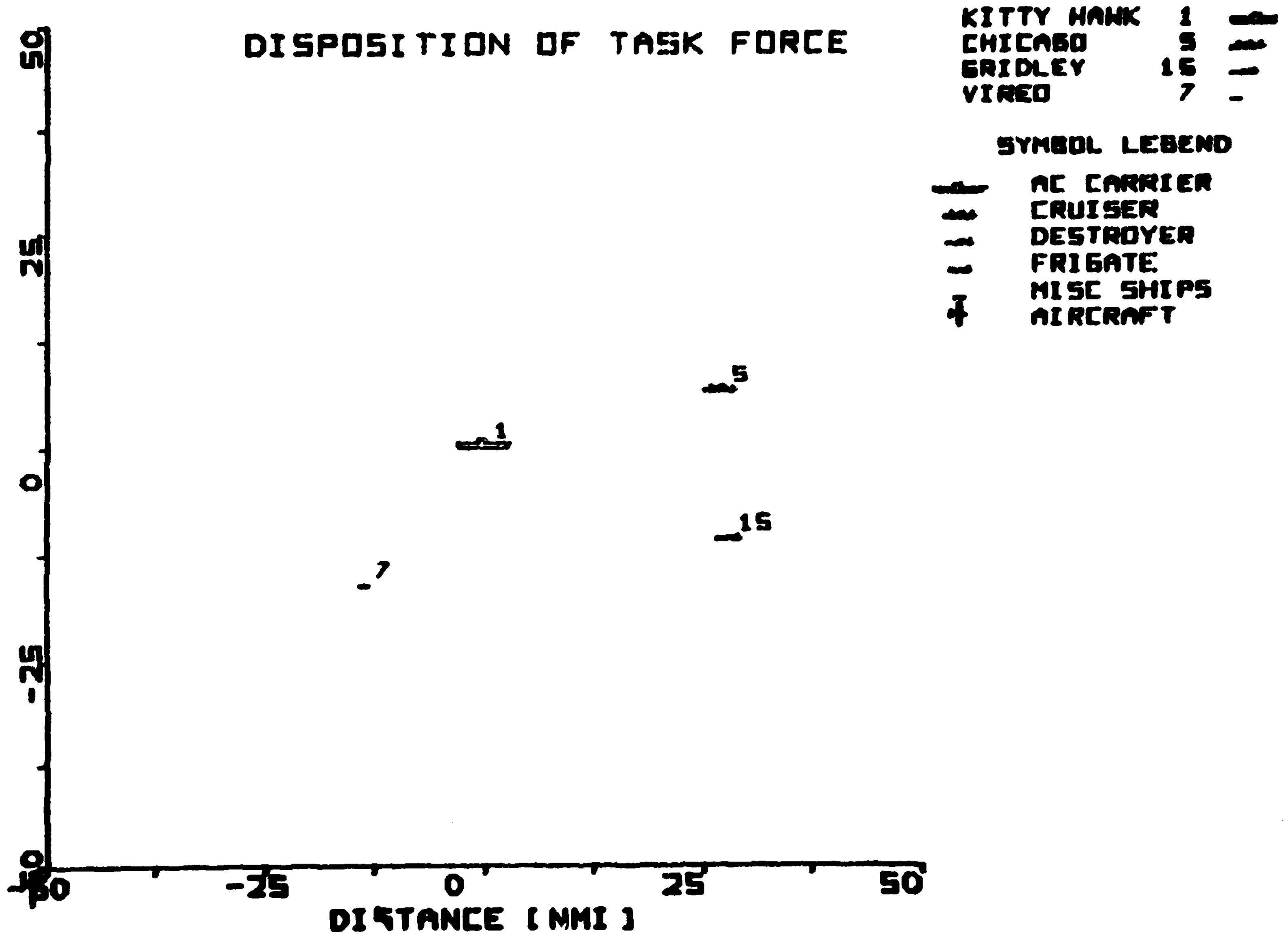


Figure C-2. Scenario 2

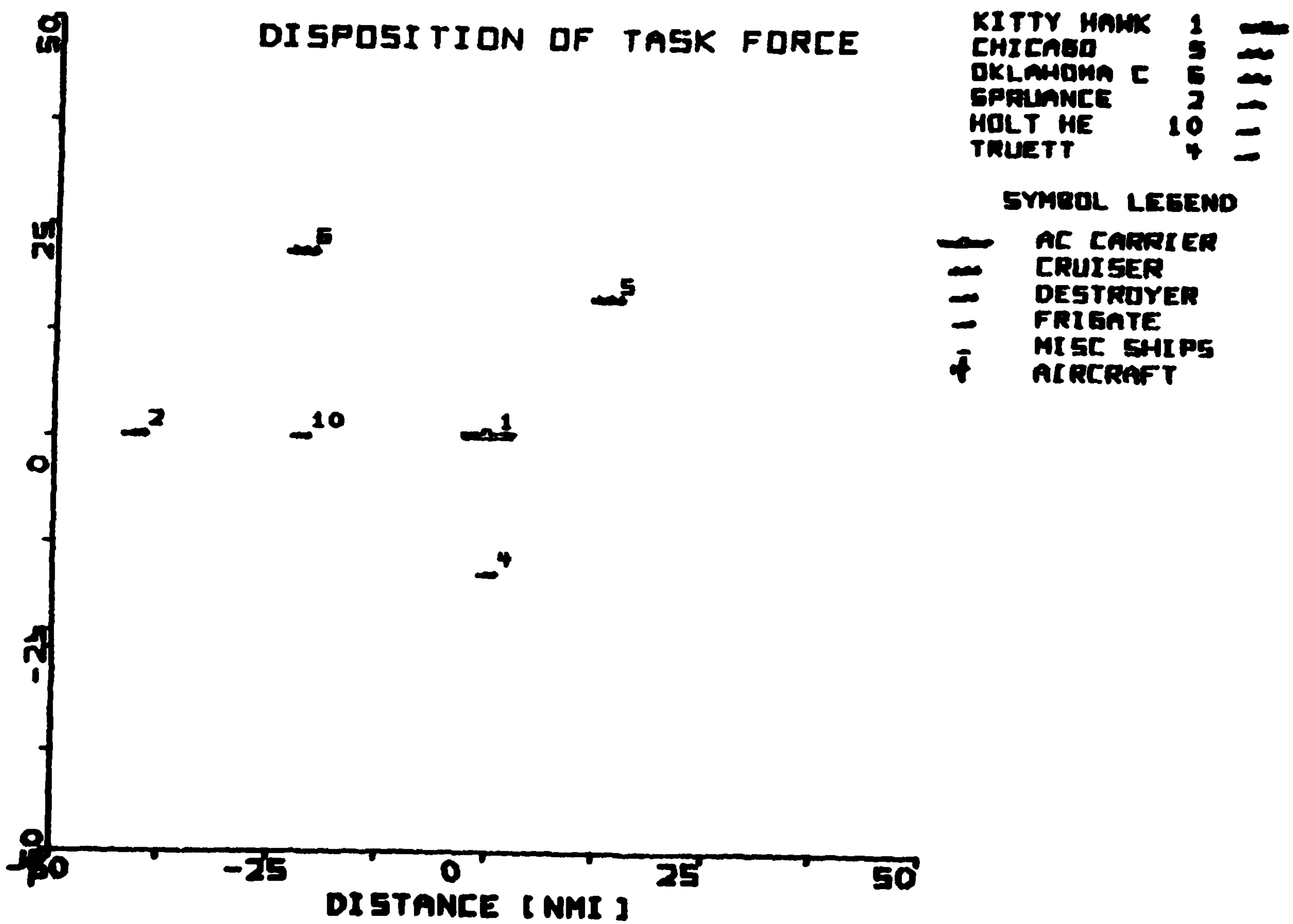


Figure C-3. Scenario 3

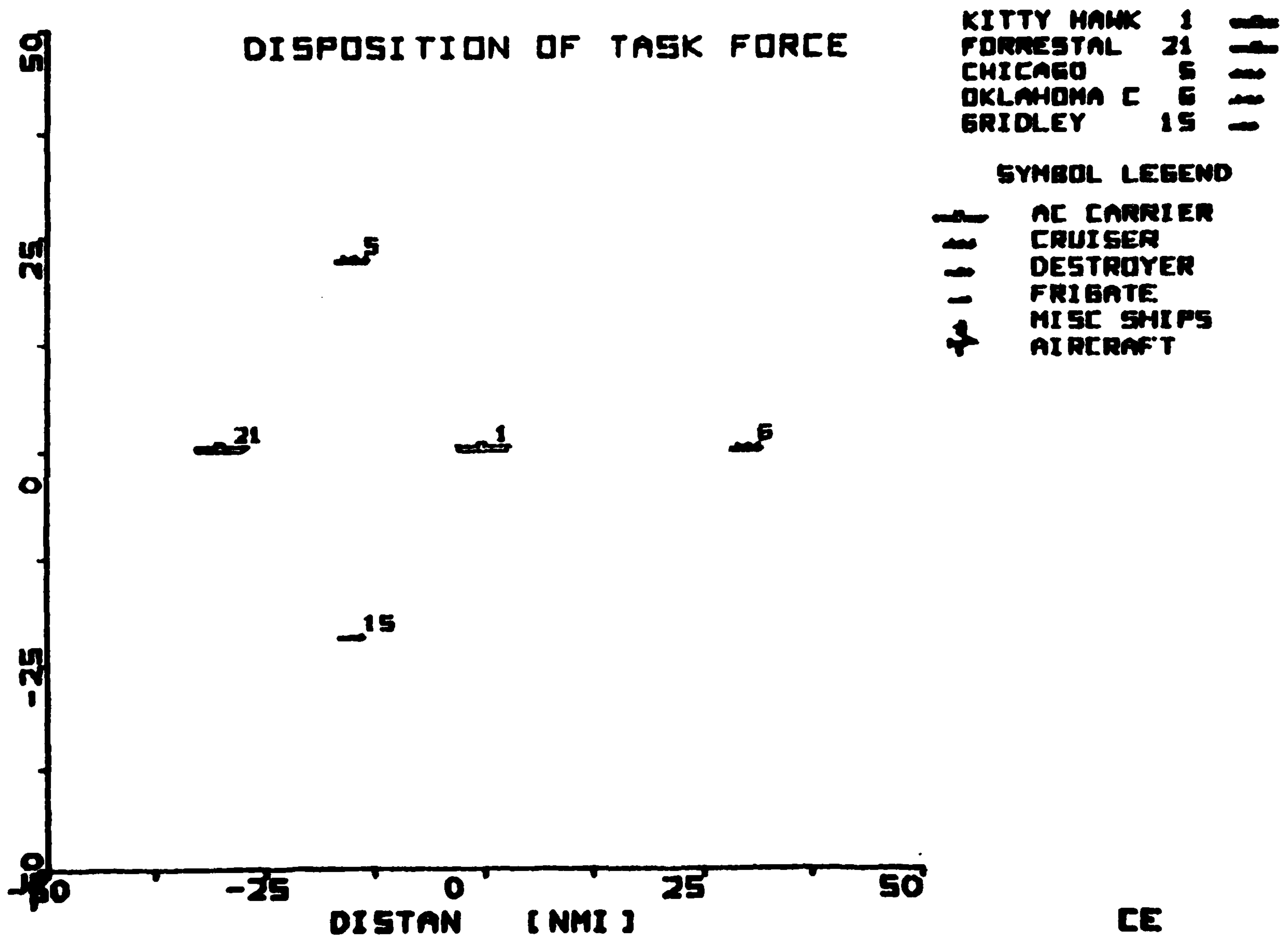


Figure C-4. Scenario 4

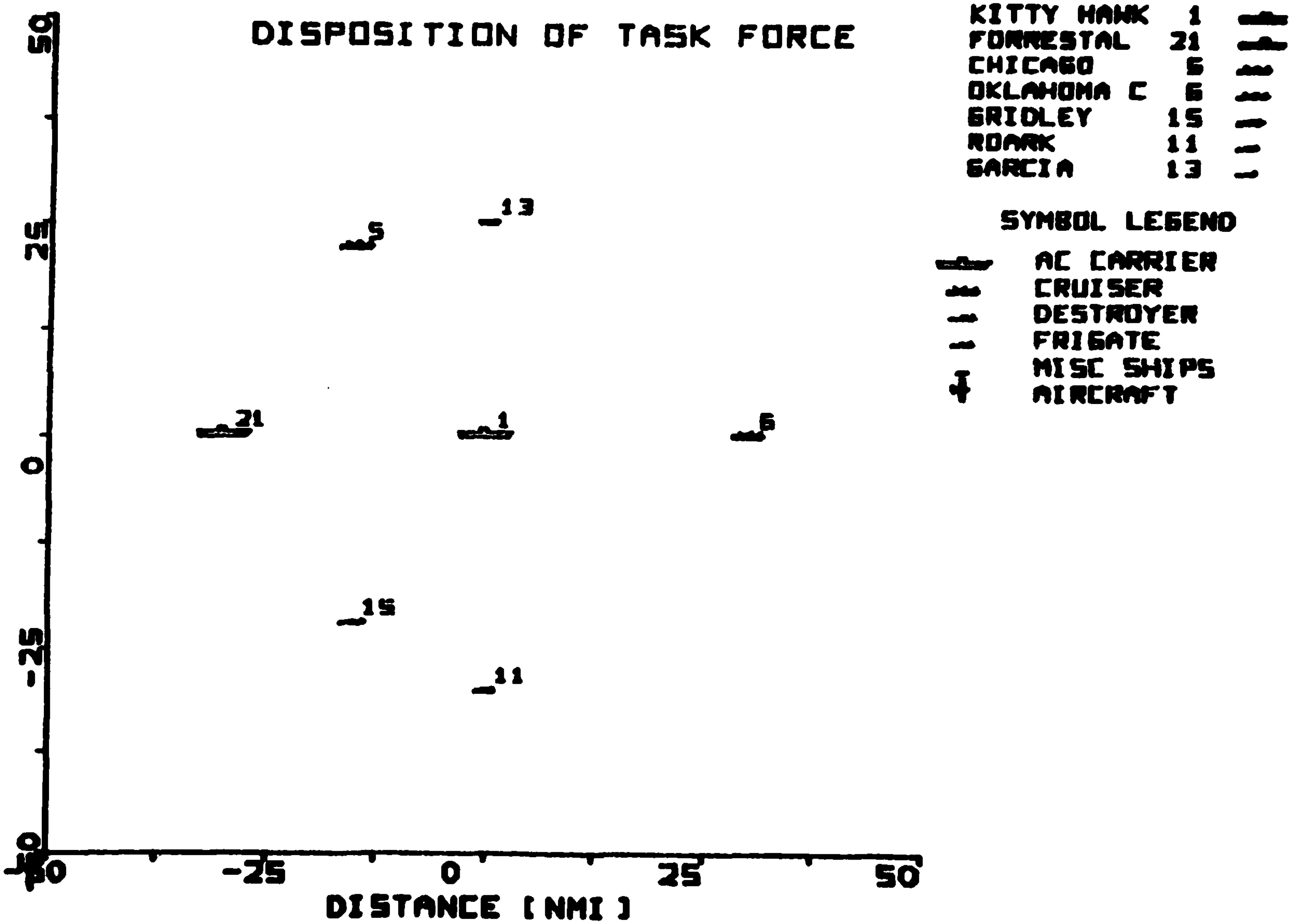


Figure C-5. Scenario 5

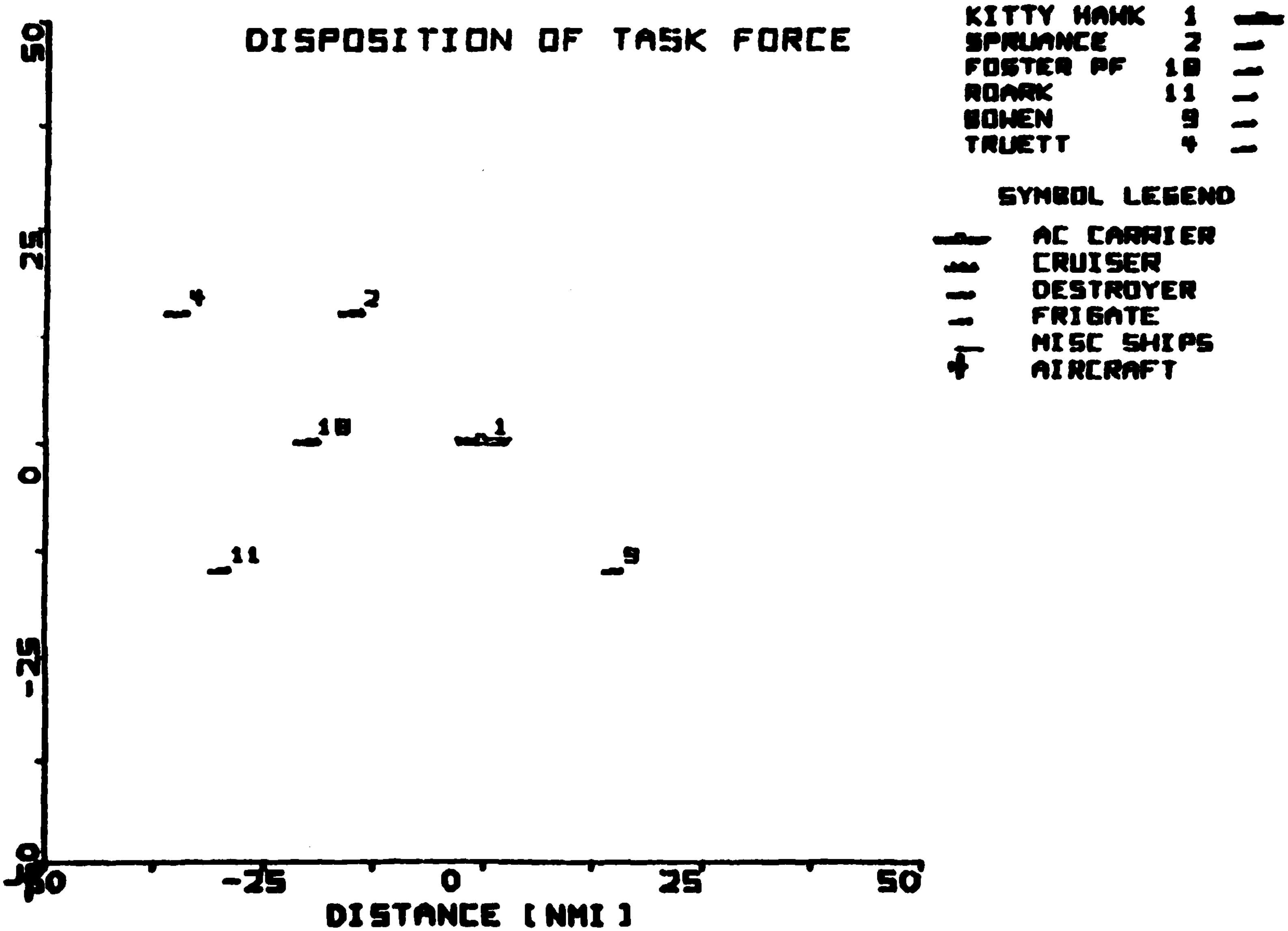


Figure C-6. Scenario 6

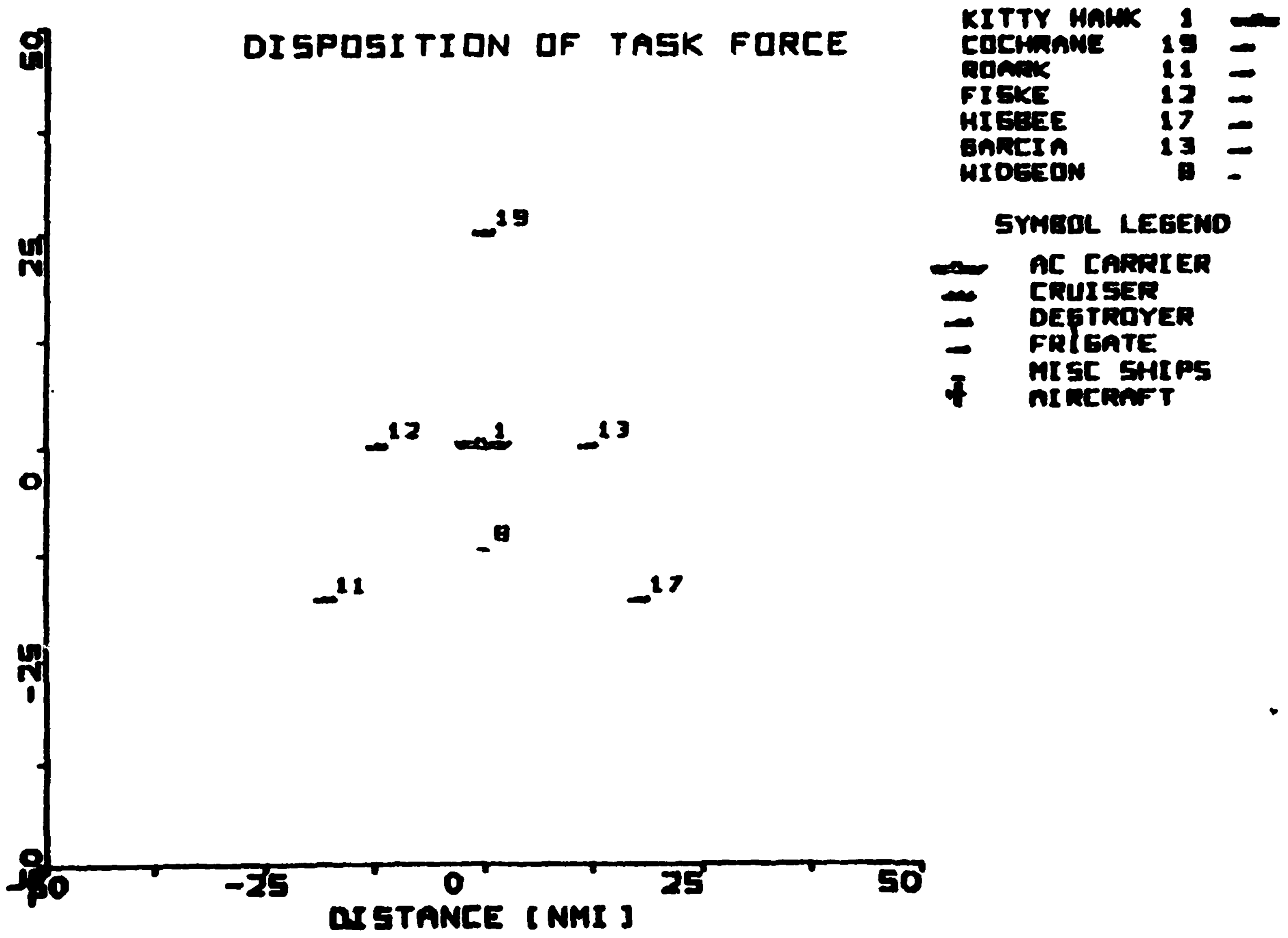


Figure C-7. Scenario 7

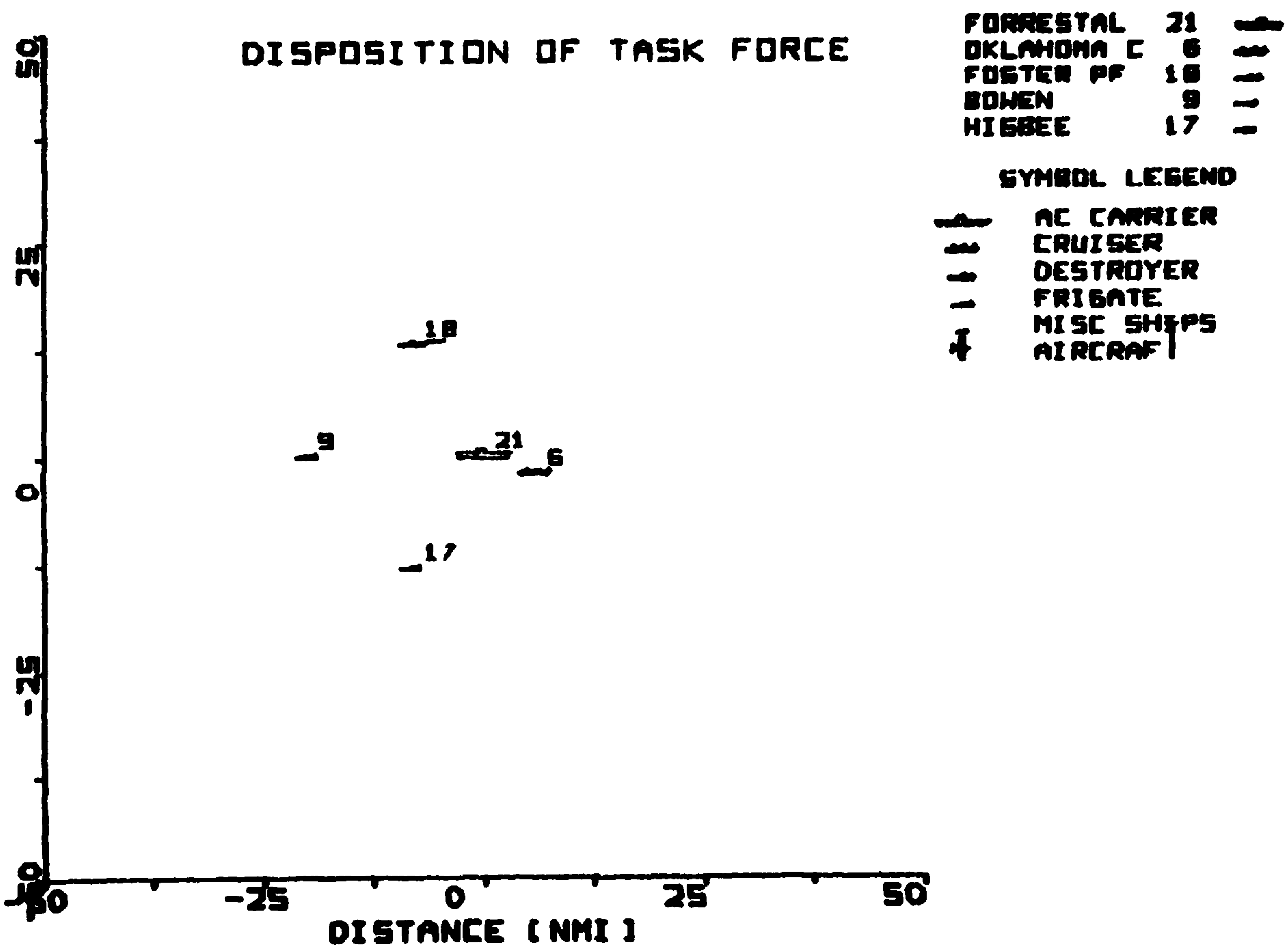


Figure C-8. Scenario 8

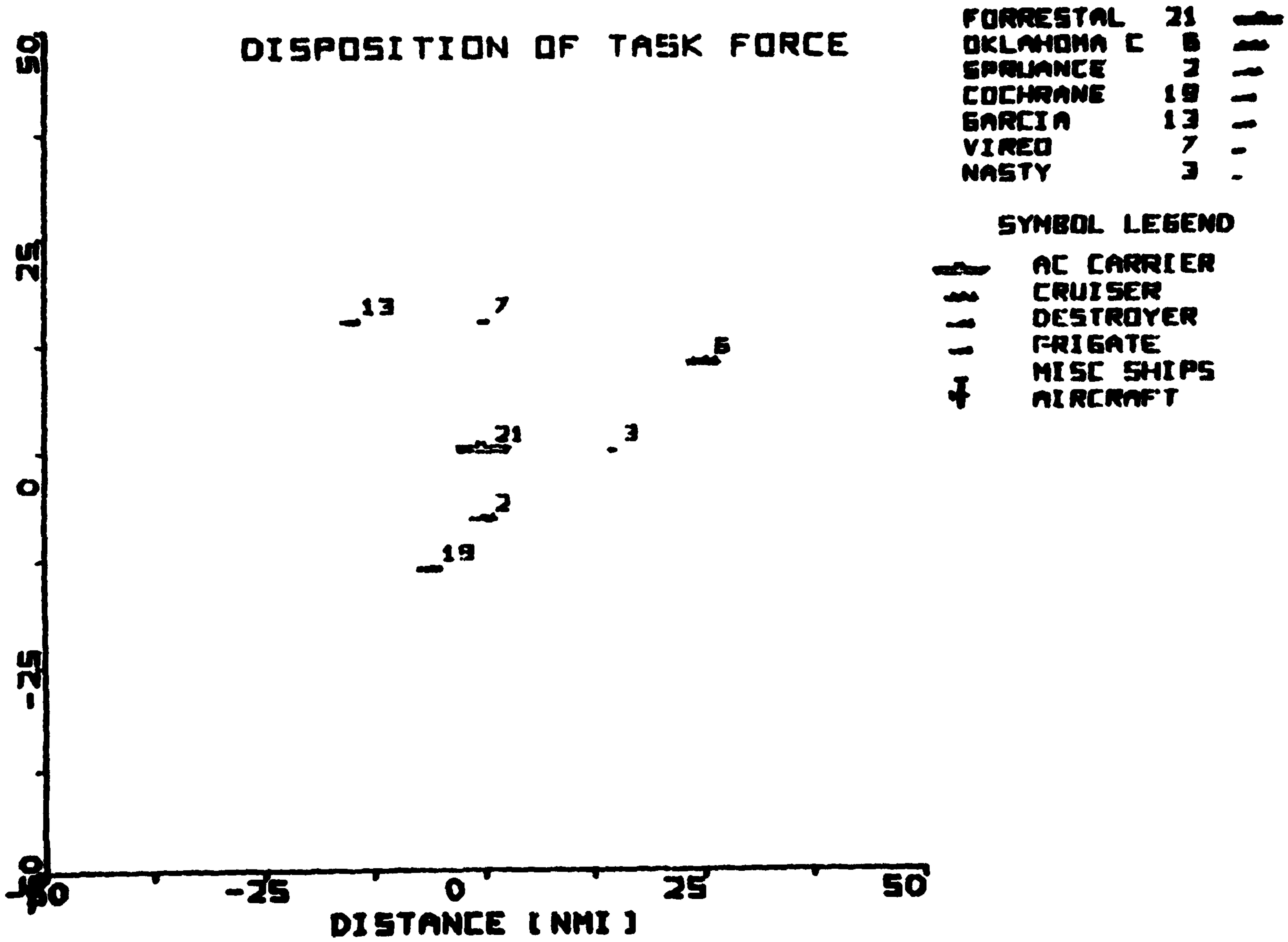


Figure C-9. Scenario 9

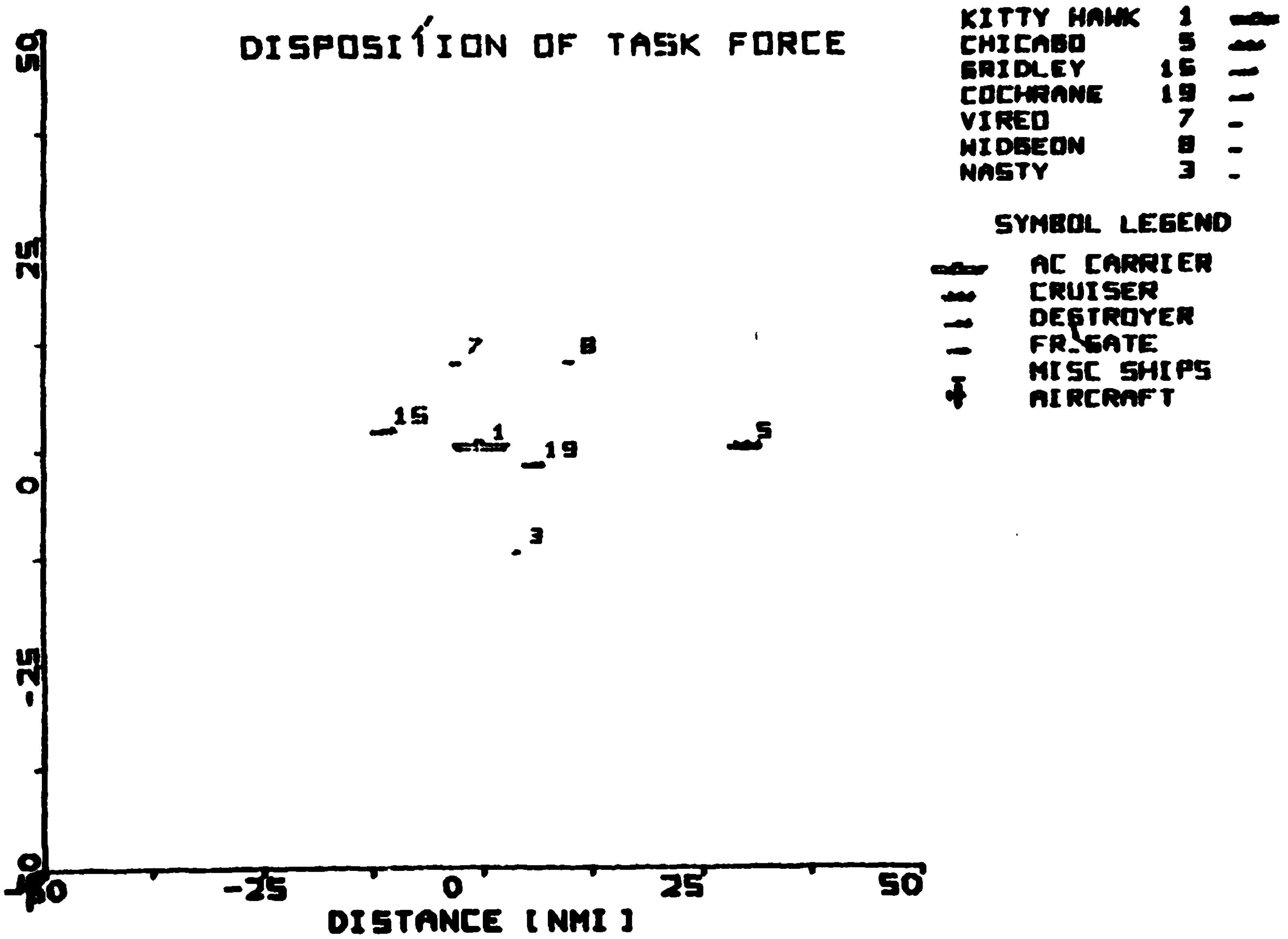


Figure C-10. Scenario 10

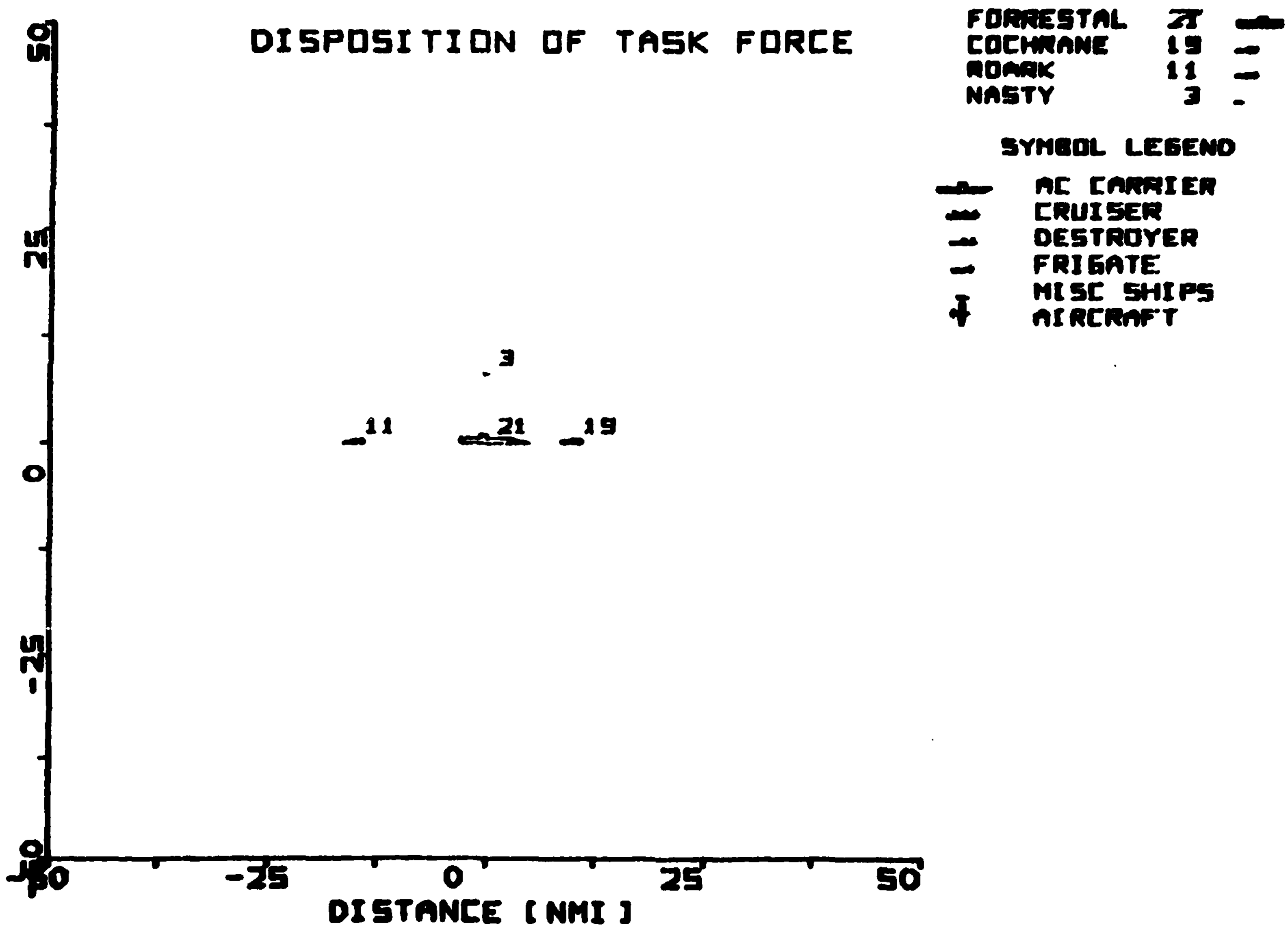


Figure C-11. Scenario 11

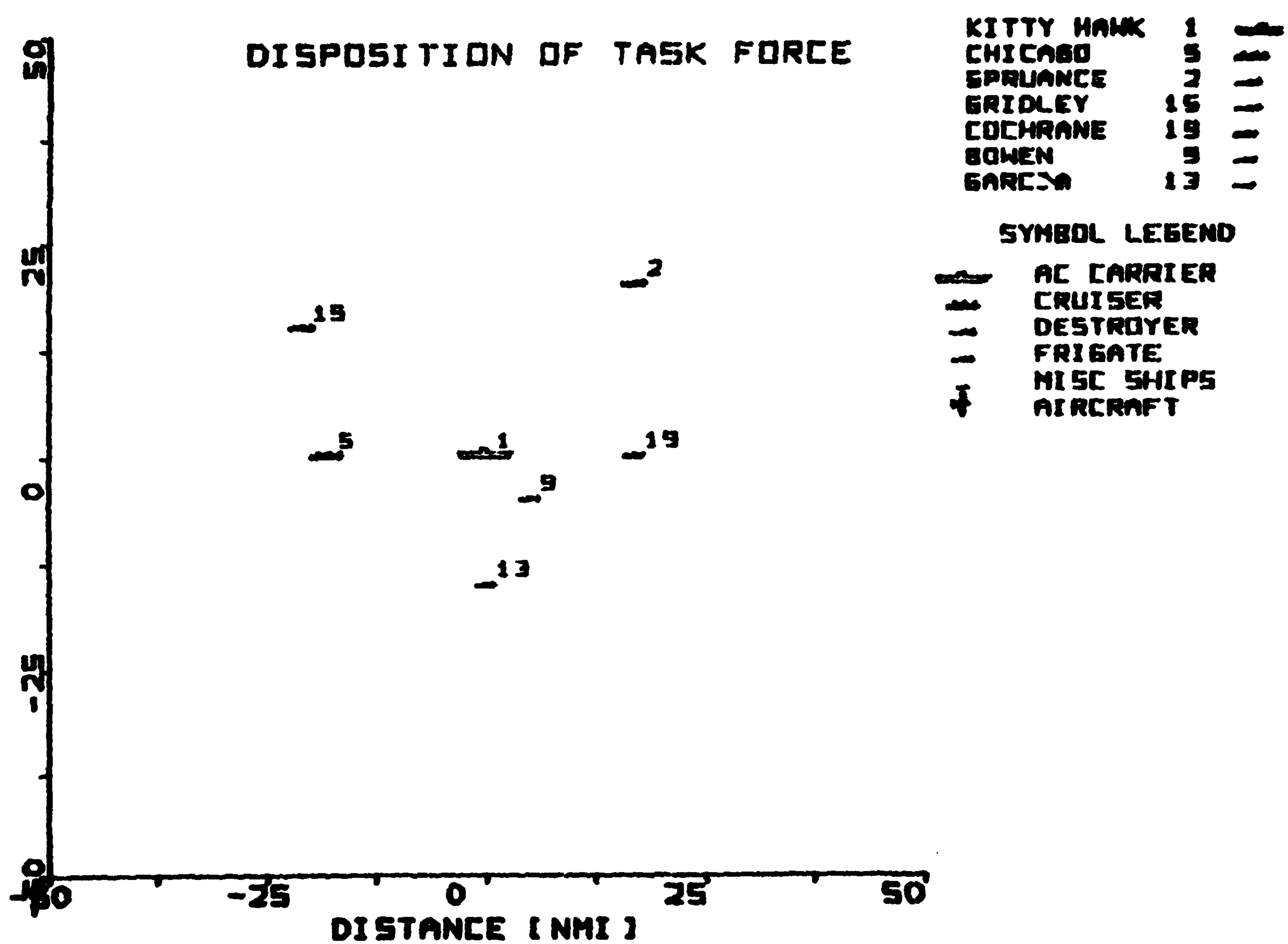


Figure C-12. Scenario 12

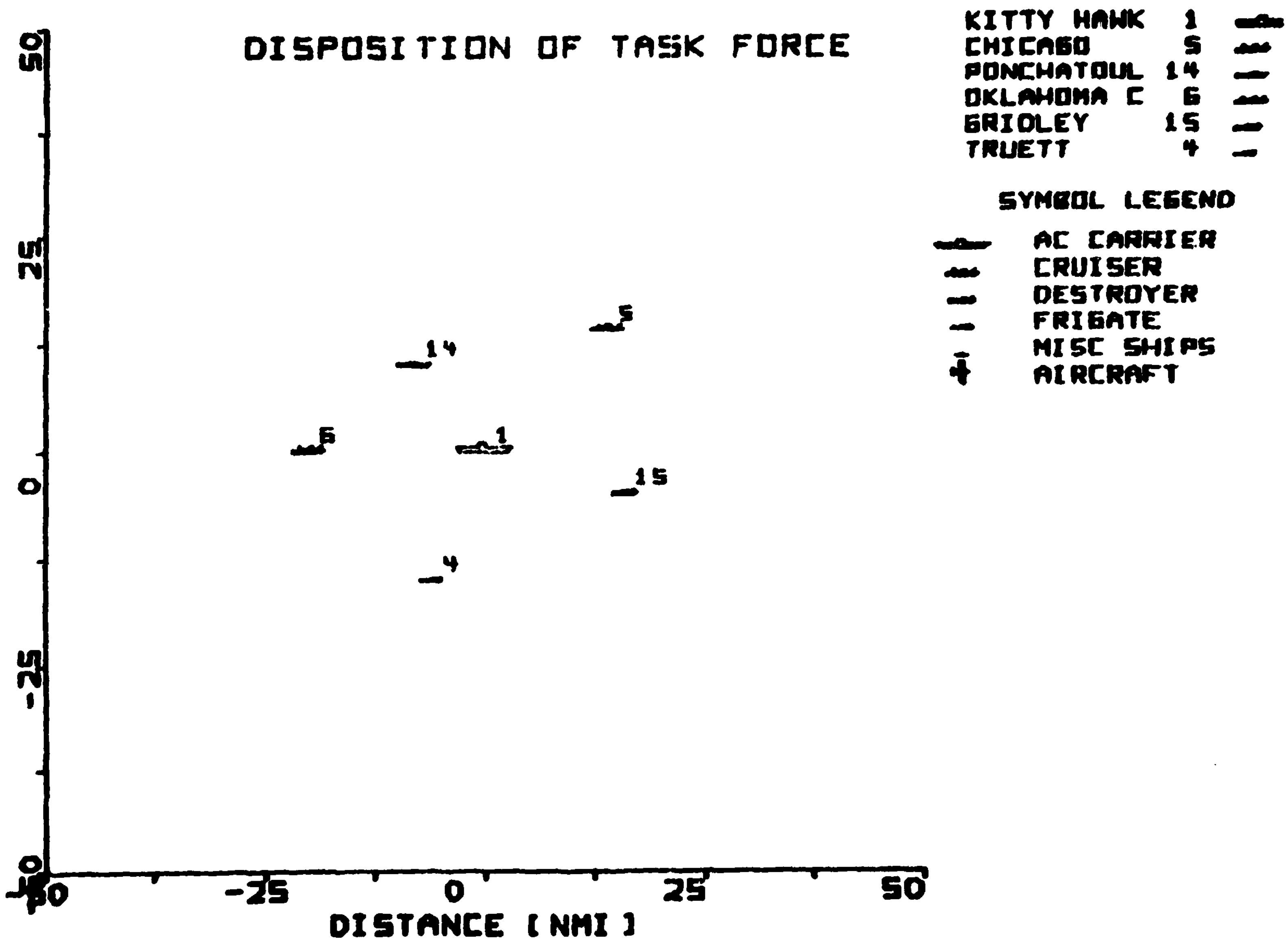


Figure C-13. Scenario 13

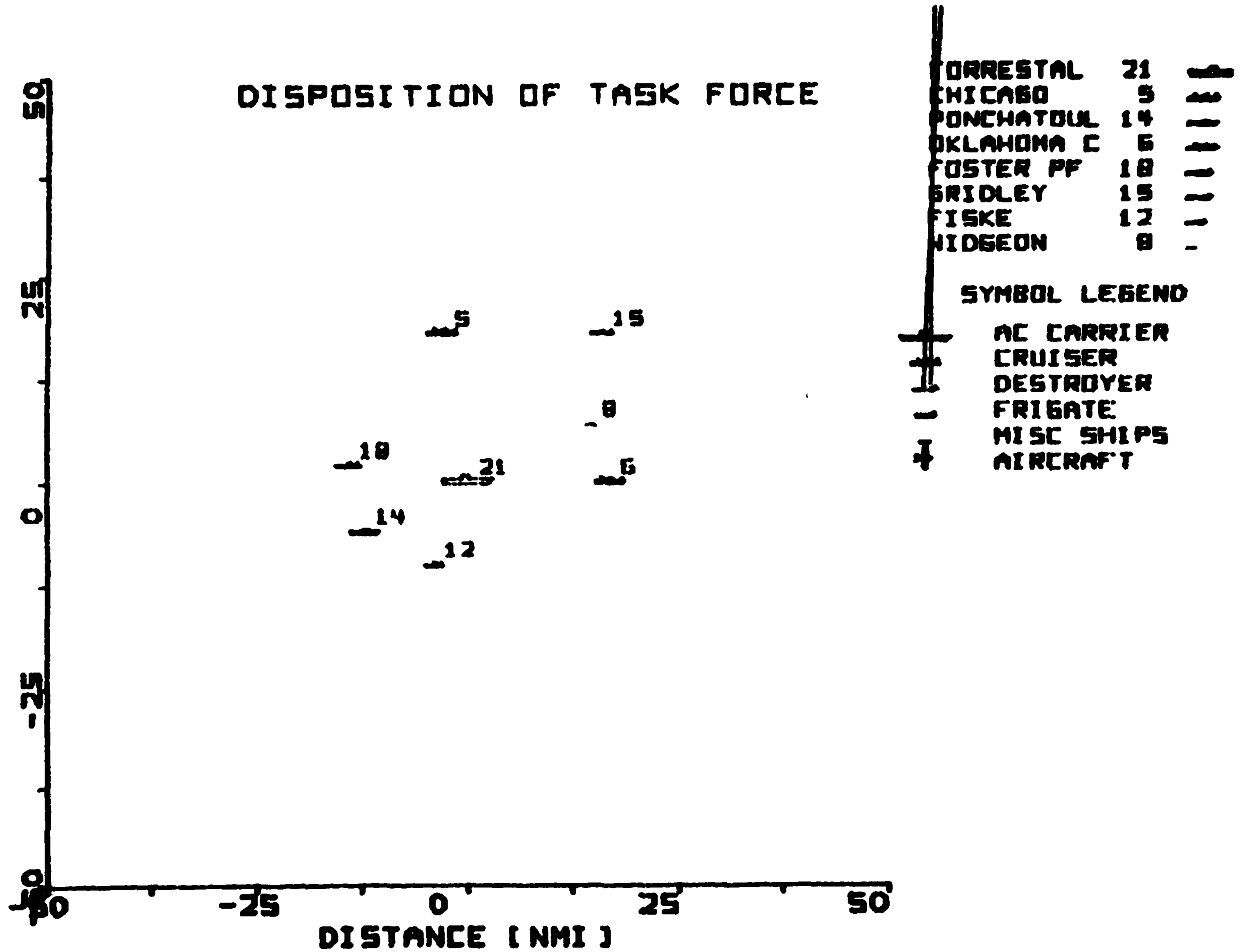


Figure C-14. Scenario 14

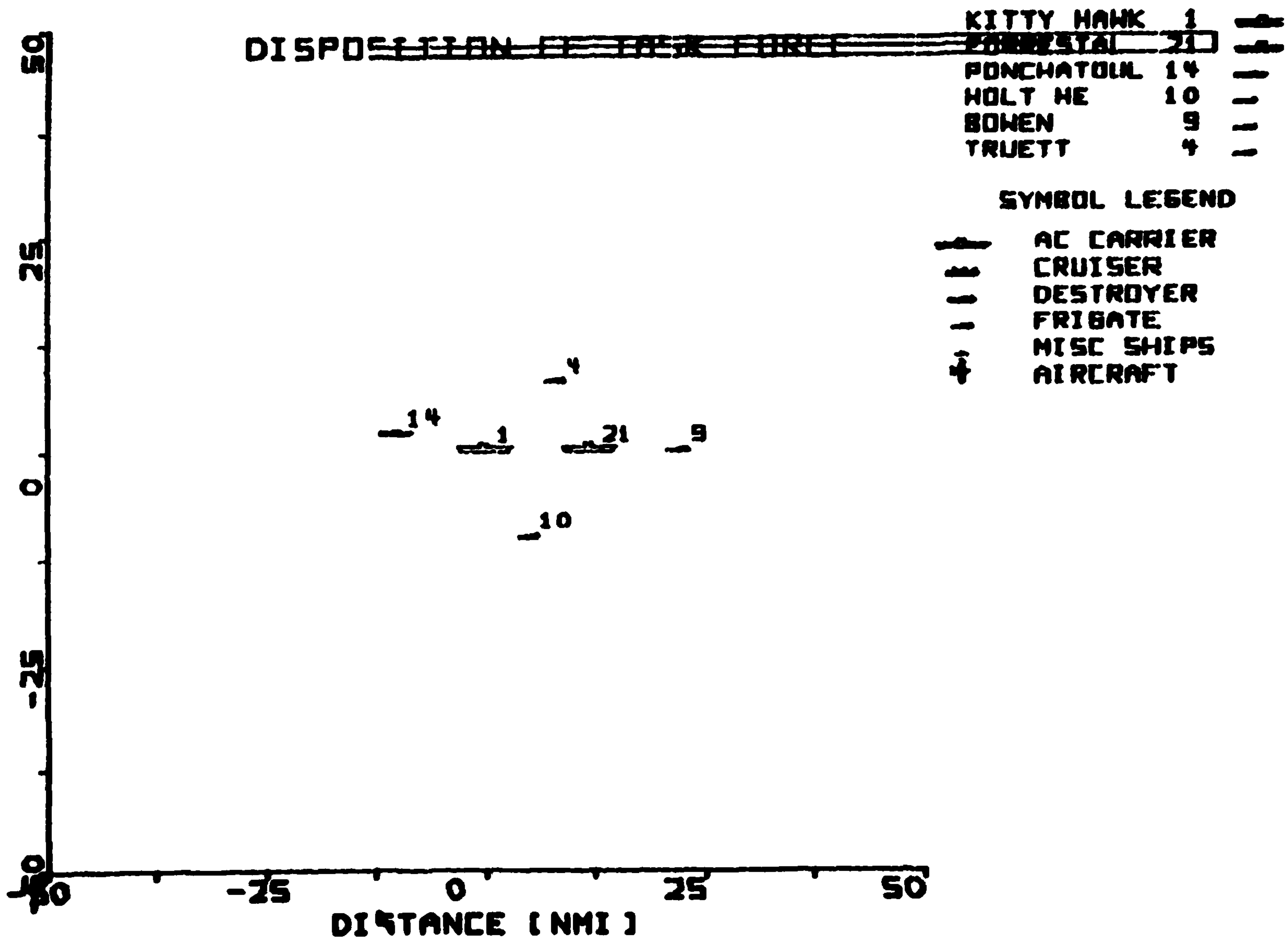


Figure C-15. Scenario 15

Distribution List

Director, Engineering Psychology
Programs (Code 455)
Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217 (5 cys)

Defense Documentation Center
Cameron Station, Bldg. 5
Alexandria, Va 22314 (12 cys)

CDR Paul Chatelier
Office of the Deputy Under Secretary
of Defense
OUSDRE (E&LS)
Pentagon, Room 3D129
Washington, D.C. 20301

CAPT John Duncan
Office of the Secretary of Defense
(C3I)
Pentagon, Room 3C200
Washington, D.C. 20301

Dr. Craig Fields
Director, Cybernetics Technology
Office
Defense Advanced Research Projects
Agency
1400 Wilson Boulevard
Arlington, Va 22209

Office of the Chief of Naval
Operations, OP987H
Personnel Logistics Plans
Washington, D.C. 20350

Dr. A. L. Slafkosky
Scientific Advisor
Commandant of the Marine Corps
Code RD-1
Washington, D.C. 20380

Commanding Officer
ONR Eastern/Central Regional Office
ATTN: Dr. J. Lester
Bldg. 114, Section D
666 Summer Street
Boston, Ma 02210

Commanding Officer
ONR Branch Office
ATTN: Dr. Charles Davis
536 South Clark Street
Chicago, IL 60605

Commanding Officer
ONR Western Regional Office
ATTN: Dr. E. Gloye
1030 East Green Street
Pasadena, Ca 91106

Commanding Officer
ONR Western Regional Office
ATTN: Mr. R. Lawson
1030 East Green Street
Pasadena, Ca 91106

Tactical Development & Evaluation Support
Code 230
Office of Naval Research
800 North Quincy Street
Arlington, Va 22217

Naval Analysis Programs
Code 431
Office of Naval Research
800 North Quincy Street
Arlington, Va 22217 (2 cys)

Operations Research Programs
Code 434
Office of Naval Research
800 North Quincy Street
Arlington, Va 22217

Statistics and Probability Program
Code 436
Office of Naval Research
800 North Quincy Street
Arlington, Va 22217

Information Systems Program
Code 437
Office of Naval Research
800 North Quincy Street
Arlington, Va 22217

Distribution List

Dr. James McGrath
Code 311
Navy Personnel Research and
  Development Center
San Diego, Ca 92152

Management Support Department
Code 210
Navy Personnel Research and
  Development Center
San Diego, Ca 92152

Naval Electronics Systems Command
Human Factors Engineering Branch
Code 4701
Washington, D.C. 20360

Director
Naval Research Laboratory
Technical Information Division
Code 2627
Washington, D.C. 20375 (6 cys)

Mr. Arnold Rubinstein
Naval Material Command
NAVMAT 08D22
Washington, D.C. 20360

Commander, Naval Electronics
  Systems Command
Command and Control Division
Code 530
Washington, D.C. 20360

Dr. John Silva
Head, Human Factors Division
Naval Ocean Systems Center
San Diego, Ca 92152

Dr. Jesse Orlansky
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Va 22202

Human Factors Department
Code N215
Naval Training Equipment Center
Orlando, Fl 32813

Dr. Gary Poock
Operations Research Department
Naval Postgraduate School
Monterey, Ca 92940

Dr. Joseph Zeidner
Technical Director
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, Va 22333

Dr. Donald A. Topmiller
Chief, Systems Effectiveness
  Branch
Human Engineering Division
Wright Patterson AFB, Oh 45433

Dr. H. W. Sinaiko
Smithsonian Institution
801 N. Pitt Street
Alexandria, Va 22314

Office of the Chief of Naval
  Operations OP942
Pentagon
Washington, D.C. 20350

Office of the Chief of Naval
  Operations OP987C
R&D Plans Division
Washington, D.C. 20350

Commander
Naval Electronics Systems Command
C3 Project Office
PME 108-1
Washington, D.C. 20360

CDR P. M. Curran
Human Factors Engineering Division
Code 604
Naval Air Development Center
Warminster, Pa 18974

M. L. Metersky
Naval Air Development Center
Code 5424
Warminster, Pa 18974

Distribution List

Dr. Edgar M. Johnson, Director
Organizations & Systems Research Laboratory
U.S. Army Research Laboratory
5001 Eisenhower Avenue
Alexandria, Va 22333

Dr. David Dianich
Chairman, Dept. of Business and Economics
Salisbury State College
Salisbury, Md 21801

Mr. Victor Monteleon
Naval Ocean Systems Center
San Diego, Ca 92152

Commander, Naval Electronics Systems Command
ELEX-03
Washington, D.C. 20360

CDR Richard Schlaff
NIPSSA
Hoffman Bldg. #1
2461 Eisenhower Avenue
Alexandria, Va 22331

Dr. Chantee Lewis
Management Department
Naval War College
Newport, RI 02840

Dr. John Shore
Naval Research Laboratory
Code 5403
Communications Sciences Division
Washington, D.C. 20375

Dr. Meredith Crawford
American Psychological Association
Office of Educational Affairs
1200 17th Street, N.W.
Washington, D.C. 20036

Dr. William Dejka
ACCAT
Naval Ocean Systems Center
San Diego, Ca 92152

Mr. Merlin Malehorn
Office of the Chief of Naval Operations (OP 102)
Washington, D.C. 20350

Dr. S. D. Epstein
Analytics
2500 Maryland Road
Willow Grove, Pa 19090

Dr. Amos Freedy
Perceptronics, Inc.
6271 Variel Avenue
Woodland Hills, Ca 91364

Dr. G. Hurst
Univeristy of Pennsylvania
Wharton School
Philadelphia, Pa 19174

Dr. Miley Merkhofer
Stanford Research Institute
Decision Analysis Group
Menlo Park, Ca 94025

Dr. George E. Pugh
Decision-Science Applications, Inc.
1500 Wilson Boulevard
Arlington, Va 22209

Dr. Arthur Siegel
Applied Psychological Services
Science Center
404 E. Lancaster Street
Wayne, Pa 19087

Mr. David Walsh
Integrated Sciences Corporation
1640 Fifth Street
Santa Monica, Ca 90401

LCDR J. A. Sears
Department of MIS
College of Business Administration
University of Arizona
Tucson, Az 85721

I. R. Mirman
Asst for Special Projects
HQ AFSC-DL
Andrews AFB, Md 20334

Distribution List

Mr. Joseph Wohl
MITRE Corporation
Box 208
Bedford, Ma 01730

Dr. Kenneth Gardner
Applied Psychology Unit
Admirality Marine Technology
Establishment
Teddington, Middlesex, TW11 OLN
ENGLAND

Mr. Tim Gilbert
MIRTRE Corporation
1820 Dolly Madison Blvd
McLean, Va 22102

Mr. Leslie Innes
Defense and Civil Institute
of Environmental Medicine
P.O. Box 2000
Downsview, Ontario M3M 3B9
Canada

Dr. Rex Brown
Decision Science Consortium
Suite 421
7700 Leesburg Pike
Falls Church, Va 22043

Dr. A. C. Miller, III
Applied Decision Analysis
3000 Sand Hill Road
Menlo Park, Ca 94025

Administrative Contracting Officer
DCASMA Baltimore
Hampton Plaza Building
Room 200
Towson, Md 21204